White

Locomotive Machine Friction

LOCOMOTIVE MACHINE FRICTION

BY

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THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

PHARES LEMAR WHITE

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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LOCOMOTIVE MACHINE FRICTION.

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LOCOMOTIVE MACHINE FRICTION.

Introduction.

Definition of Subject.

Locomotive Machine Friction is the power absorbed in overcoming the frictional resistance of the moving parts of a locomotive between the cylinders and drawbar, together with the rolling resistance of the drivers. Restated as a formula, which is applicable to laboratory tests only, it may be defined as indicated horse-power minus drawbar horse power.

A knowledge of the laws governing locomotive machine friction and the amount of power absorbed under varying conditions of operation, would be of benefit in determining what might be expected of a locomotive as regards the net tractive effort available.

Previous Investigations.

Repeated attempts to discover the exact relation of machine friction to some of the more readily determined factors of locomotive operation, such as mean effective pressure, speed and cut-off have not been entirely successful and at present there are at least four distinctly different methods of making locomotive machine friction determinations.

Dr. W. F. M. Goss, from data obtained at Purdue University, decided to express locomotive machine friction by the formula

$$3.8 \frac{d^2 L}{D}$$

where, d = cylinder diameter in inches
L = length of stroke in feet
D = diameter of drivers in inches.

A further discussion of this method will be found elsewhere in this analysis.

Mr. Henderson, in "Locomotive Operation", concludes that machine friction may be fairly well represented by the following analysis:

Driving box journals, ...	2.5%
Main pin bearings, ...	1.7%
Side rod bearings, ...	1.7%
Crosshead, ...	.4%
Piston and rod, ...	1.0%
Valves, ...	.6%
Link motion, ...	.6%
TOTAL	8.5%

In this analysis Mr. Henderson has based all of his percentages on the total indicated horse-power. From this he arrives at the formula, machine friction is equal to .15 V + C, in percentage of indicated horse-power, where V equals speed in miles per hour and C is a constant whose value may vary from 2 to 8 depending upon speed and class of work. The larger values being the better for slow, heavy freight service.

Later investigators among whom are, Mr. F. J. Cole, Consulting Engineer for the American Locomotive Company, have adopted a somewhat different method of attack. In his investigation, Mr. Cole expresses all results in pounds of tractive effort per ton of weight on locomotive drivers. After having collected data from the Purdue plant, the Pennsylvania plant at St. Louis

and elsewhere, he selects 22.2 pounds tractive effort per ton weight on drivers as being a representative figure for any locomotive under any condition. It is apparent that such a generalization would not be satisfactory where definite results for known conditions were desired.

The American Railway Engineering Association has developed a formula which gives the total machine friction in pounds of tractive effort. The formula is, total machine friction expressed as pounds tractive effort equals $18.7\ T + 80\ A$, where T equals tons-weight on drivers and A equals number of driving axles. This formula takes into account both weight variation and type. For this reason the formula is more general than the one devised by Mr. Cole.

Comparison of the four methods of expressing locomotive machine friction which have just been given together with fuller discussion of the several methods, will be presented later.

It is evident that the existing generalizations leave much to be desired in the way of uniformity. The reasons for this lack of uniformity are largely due to the fact that, until recently, the data available for making such a study has been very meager. Again the greater part of the data available for this use was obtained primarily for other purposes such as, a study of firing rate, boiler conditions, coal consumption and many other things which, perhaps, did not permit of the most suitable conditions for obtaining machine friction data.

General Purpose.

The general purpose of this investigation is to establish more exact methods of expressing locomotive machine friction and its relation to other factors of locomotive operation.

Components of Locomotive Machine Friction.

A possible solution of this problem may be made by subdividing the subject as a whole into its several components somewhat as was attempted by Mr. Henderson. Such a division might be expressed as follows:

(a) Resistance due to piston.

(b) Valve friction.

(c) Stuffing-box resistance.

(d) Valve motion friction.

(e) Crosshead friction.

(f) Pin-bearing friction.

(g) Journal bearing friction.

(h) Rolling resistance of drivers.

There appears to be no good reason why such an analysis might not be made and in fact the values obtained by Mr. Henderson, if subjected to a more complete investigation, would undoubtedly yield good results. However, there are at all times present in such an analysis, a large number of variable quantities and the possibilities of a practical solution by this method are not as satisfactory as might be expected.

Weather variations, lubrication, track conditions and locomotive maintainance influence each of these items and could easily lead to erroneous conclusions. It would thus seem that for the present the most satisfactory solution would be one in which the machine friction as a whole was used and its relation to other factors of locomotive performance shown through a study of experimental data.

Prospect for a Satisfactory Determination.

As was stated in the foregoing paragraph, the possibility of establishing an exact value for each of the elements composing locomotive machine friction appears questionable. It would seem advisable, however, to attempt at present to evaluate machine friction as a whole and if possible to determine its relation to some of the more common variables, such as speed, mean effective pressure or cut-off. From this point of view the variables depending upon the component parts of machine friction will disappear from the analysis, but due to the existence of such variables and to others such as track conditions, weather and lubrication, any expression for machine friction decided upon must necessarily be expressed as variable.

A consideration of the elements of locomotive machine friction has led to the conclusion that a proper solutionfor the values of machine friction in locomotive operation, for a given locomotive or type of locomotive, will involve the measurement of the amount of power of that locomotive or type of locomotive thus absorbed over the entire range of operation. Such a measurement

will, perhaps, give some insight as to the true relation of machine friction to such variable factors as speed, cut-off or mean effective pressure.

The Data.

Laboratory tests and road tests offer the only two means for evaluating machine friction. Either may be used successfully but it frequently occurs that in road tests it is not possible to obtain all of the data desirable or to obtain data of sufficient accuracy, and as a result laboratory methods and results from laboratory tests have been largely used. In laboratory work factors such as speed, cut-off and mean effective pressure, may be kept practically constant for any desired period of time. Variables as to wind, weather and track conditions present in road tests are eliminated in laboratory tests. In this discussion, conclusions will be based on test plant results.

General Discussion.

In considering the relation of machine friction to some of the common variables of locomotive operation such as speed, cut-off and indicated horse-power, it is desirable to indicate some of the underlying principles which make this method of attack desirable.

The advantage of securing a relation between two quantities, one of which is easily determined and may be varied at will is important and such a method if reasonably accurate, would give a satisfactory way of predicting the value of machine friction for any desired condition.

The several components of locomotive machine friction might be expected to follow the general laws governing either

rolling or sliding friction as the case may be.

The laws of sliding friction have, themselves, been the subject of much discussion at various times and, as a result of this, there appears to be some difference of opinion as to what actually happens. In the case of rolling friction the amount of power thus expended is largely dependent upon the kind of surfaces in contact and the general laws governing such friction are not clearly established.

There exist certain reasons of fundamental importance why machine friction may be expected to vary with speed, cut-off or indicated horse-power. Its variation with speed is, to some extent, due to the physical characteristics of the surfaces in contact. The surfaces of metal parts are not perfectly smooth but consist of numerous irregularities of minute size, and when one surface slides over another there is always present a tendency for these irregularities to fit into one another and thus increase the surface in contact. At low speed this tendency is the most marked. With increasing speeds this effect decreases. This explanation partly accounts for the decrease in machine friction as the period of service of the locomotive is increased. It would appear from this explanation that we should expect, other conditions being equal, the amount of power consumed in machine friction to decrease with increasing speed.

This conclusion is somewhat general, but investigations along this line support it in the majority of cases and the fact that there are some variations does not necessarily invalidate the

conclusion but may indicate that other factors were present which overcame this tendency.

The relation of locomotive machine friction to cut-off has not proven a satisfactory method of solution but the influence of changes in cut-off on locomotive machine friction as a whole can not be entirely disregarded. To variations of cut-off may be charged variations in that part of machine friction which is absorbed by the movement of the valves, the loss of power in the stuffing boxes and at the piston.

It is exceedingly difficult to determine variations in the amount of power chargeable to changes of cut-off because cut-off and speed are quite closely related and it rarely occurs that a change in one is made without a change in the other. This condition introduces additional complications, the exact nature of which is not at present known.

Attempts to solve the problem by determining the relation of machine friction to load or indicated horse-power have not fulfilled the expectations of previous investigators and, because of this the consideration of such a method, will in this analysis, be meager. Reasons why such a method of attack fails are not easily established. Perhaps the most important reason for the existing discordance in machine friction values determined by this method, is due to the number of variables affected by a change in the indicated horse-power values. Speed and cut-off are generally both involved and, as has been previously shown, no definite relation concerning the effect of changes of either of these items

upon machine friction, is known.

A satisfactory solution by the use of the relation of machine friction to indicated horse-power would be of distinct advantage because it would give at once the relation of the net power available to the power in the cylinder.

As between the relations, machine friction to speed, machine friction to cut-off and machine friction to indicated horse-power , it has seemed best for the purposes of this investigation to make use of the relation between machine friction and speed.

Machine friction has been commonly expressed as horse-power, in per-cent of indicated horse-power, in terms of mean effective pressure, in terms of drawbar pull and as pounds of tractive effort per ton weight on drivers.

In the discussion of the data presented, machine friction has been expressed as pounds of tractive effort per ton weight on drivers.

Experimental Data.

In Appendix I tables 2 to 16 inclusive present the data from which all calculations and results for the complete list of locomotives were obtained.

Figures 1 to 6 inclusive present values of machine friction expressed as pounds of tractive effort in its relation to speed in miles per hour. The values plotted in these figures are all of those relating to Consolidation type locomotives, which have been collected for this investigation, and represent the results of six different locomotives operating under speed, cut-off and load conditions which varied roughly throughout the entire range of ordinary operation for this type of locomotives.

Figure 7 represents values of machine friction for an American type locomotive. The data presented is that obtained by Dr. W. F. M. Goss from experiments performed on Schenectady No. 1. The major portion of the data presented is the result of a special effort to establish the range and relation of machine friction, whereas in the other data a greater portion has been obtained from test results in which the determination of other factors of locomotive performance was the prime object. It is, perhaps, correct to say that for American type locomotives of similar size the results obtained are quite accurate. Locomotives of this size and class are, however, rapidly disappearing and it becomes desirable to determine what may be expected of more modern equipment.

Figures 8 to 11 inclusive present values of a similar nature but are for Atlantic type locomotives. Approximately the

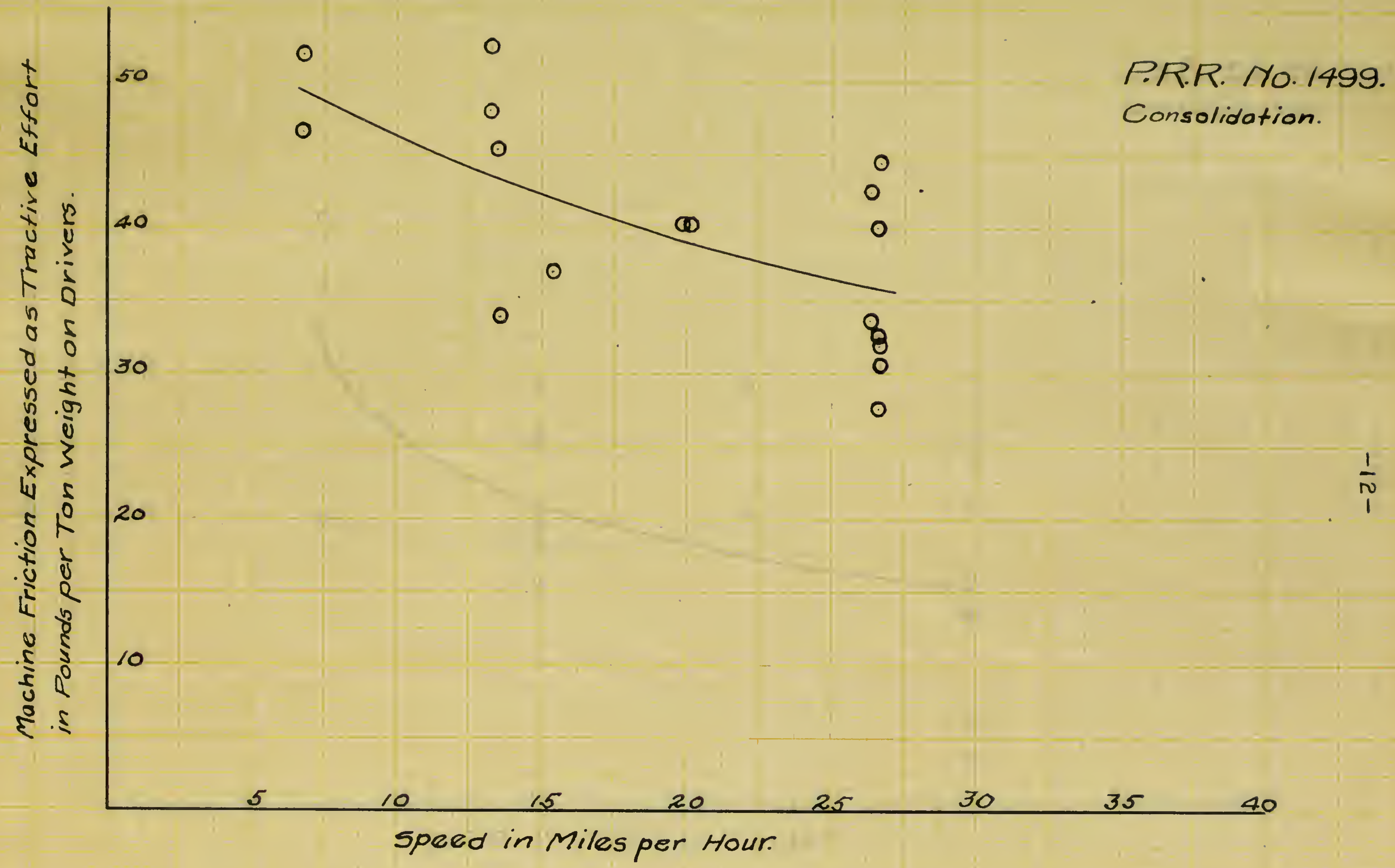


Fig 1. Relation Between Machine Friction And Speed.

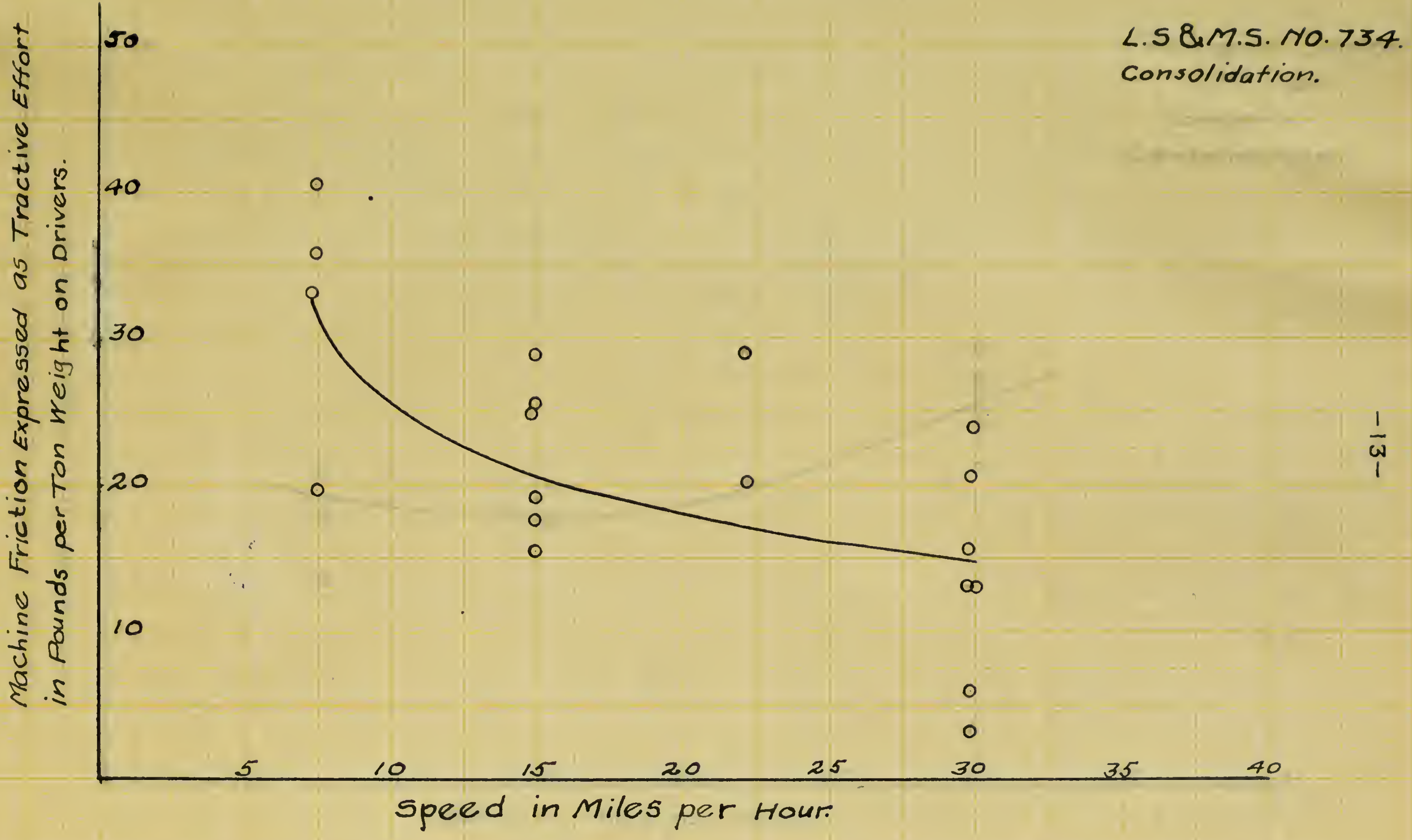


Fig. 2. Relation Between Machine Friction And Speed.

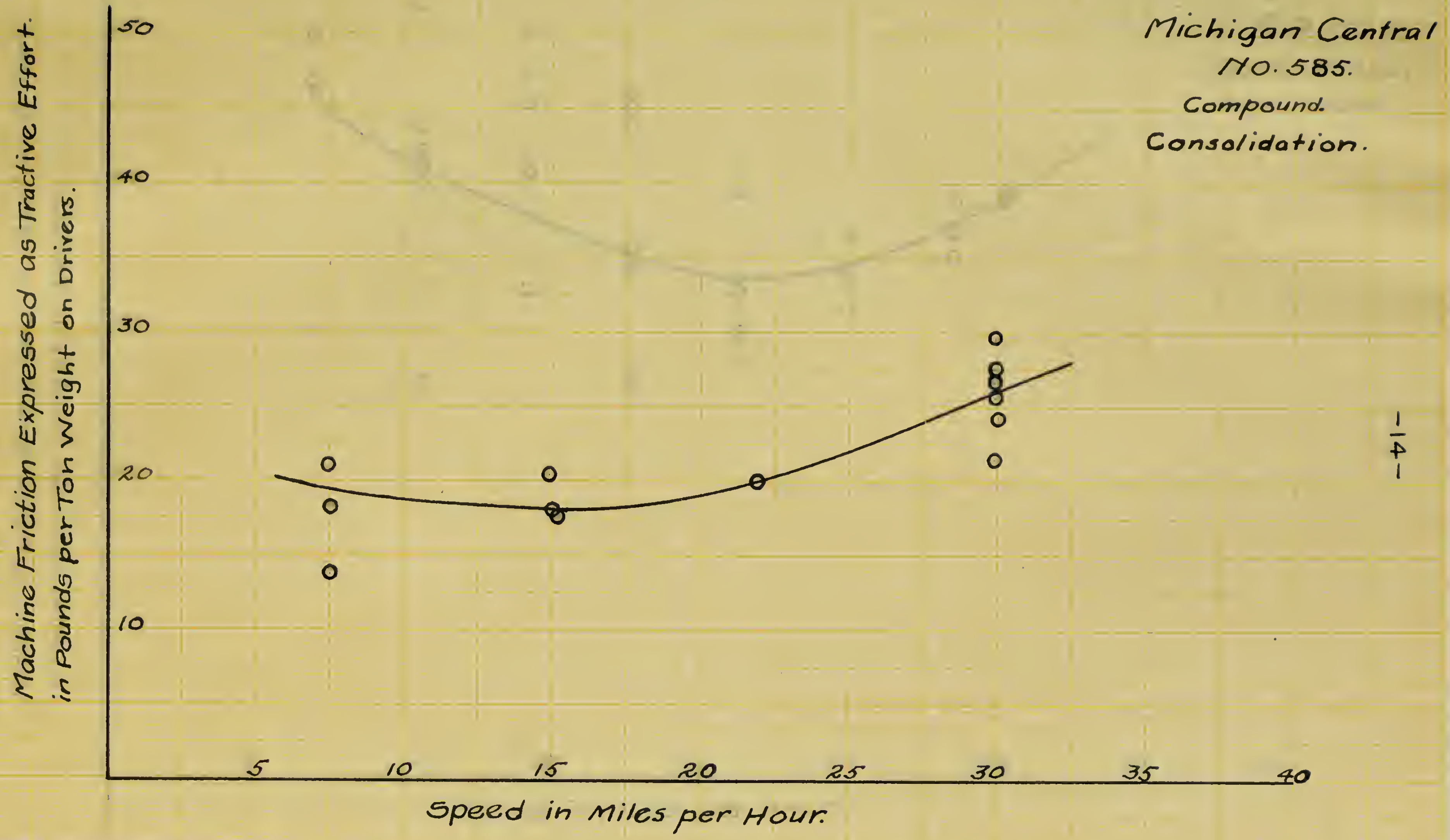


Fig. 3. Relation Between Machine Friction And Speed.

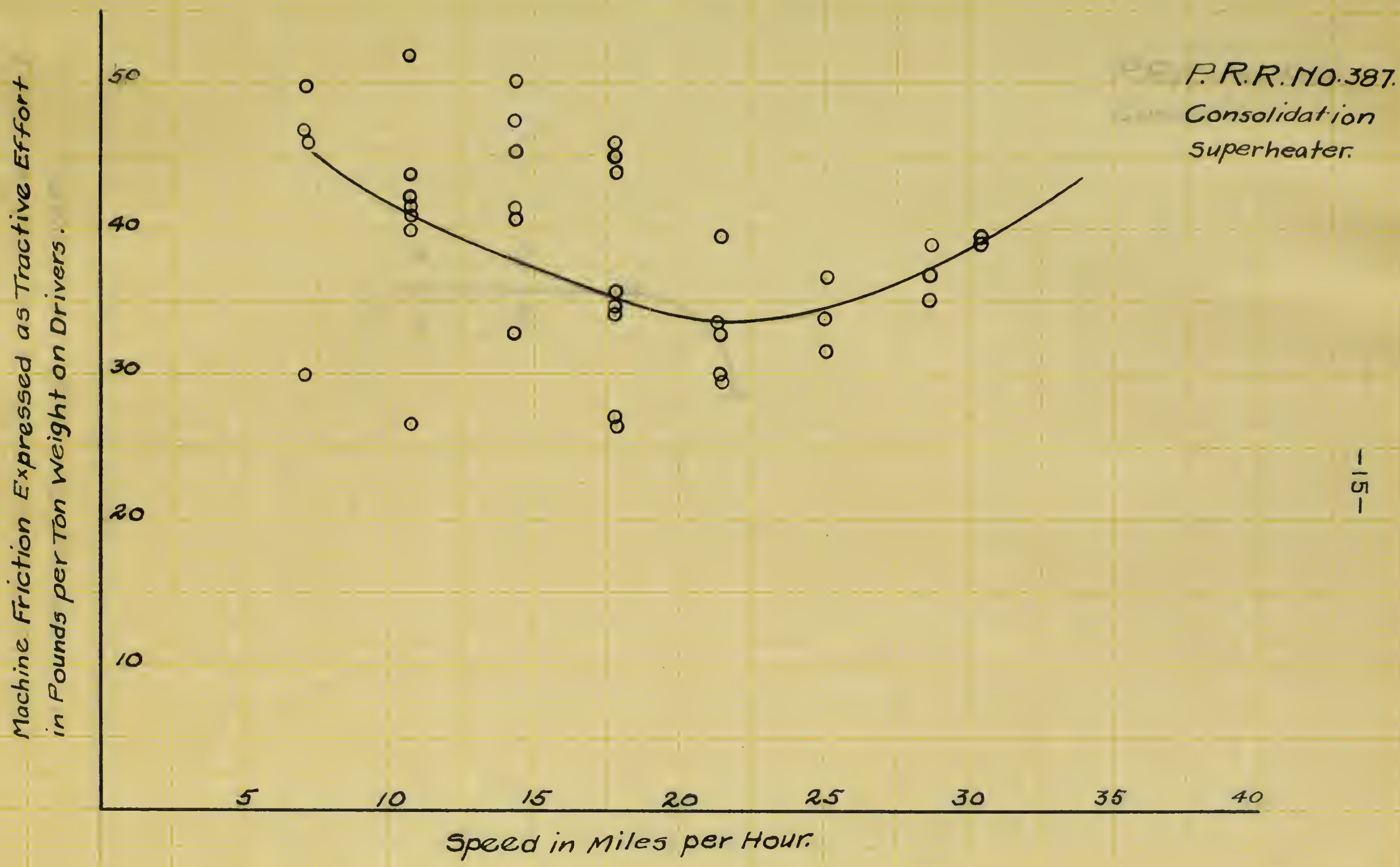


Fig. 4. Relation Between Machine Friction And Speed.

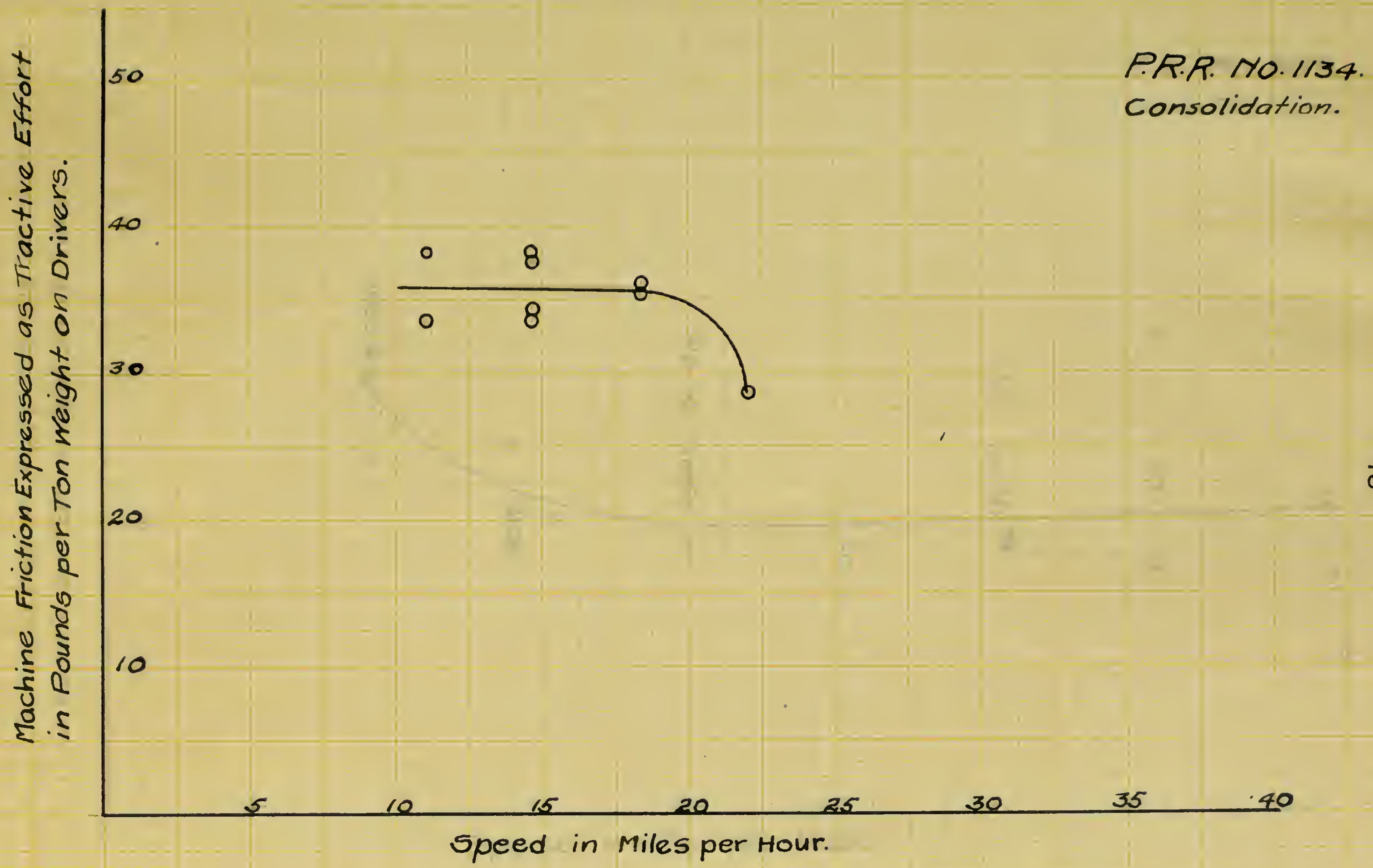


Fig. 5. Relation Between Machine Friction And Speed.

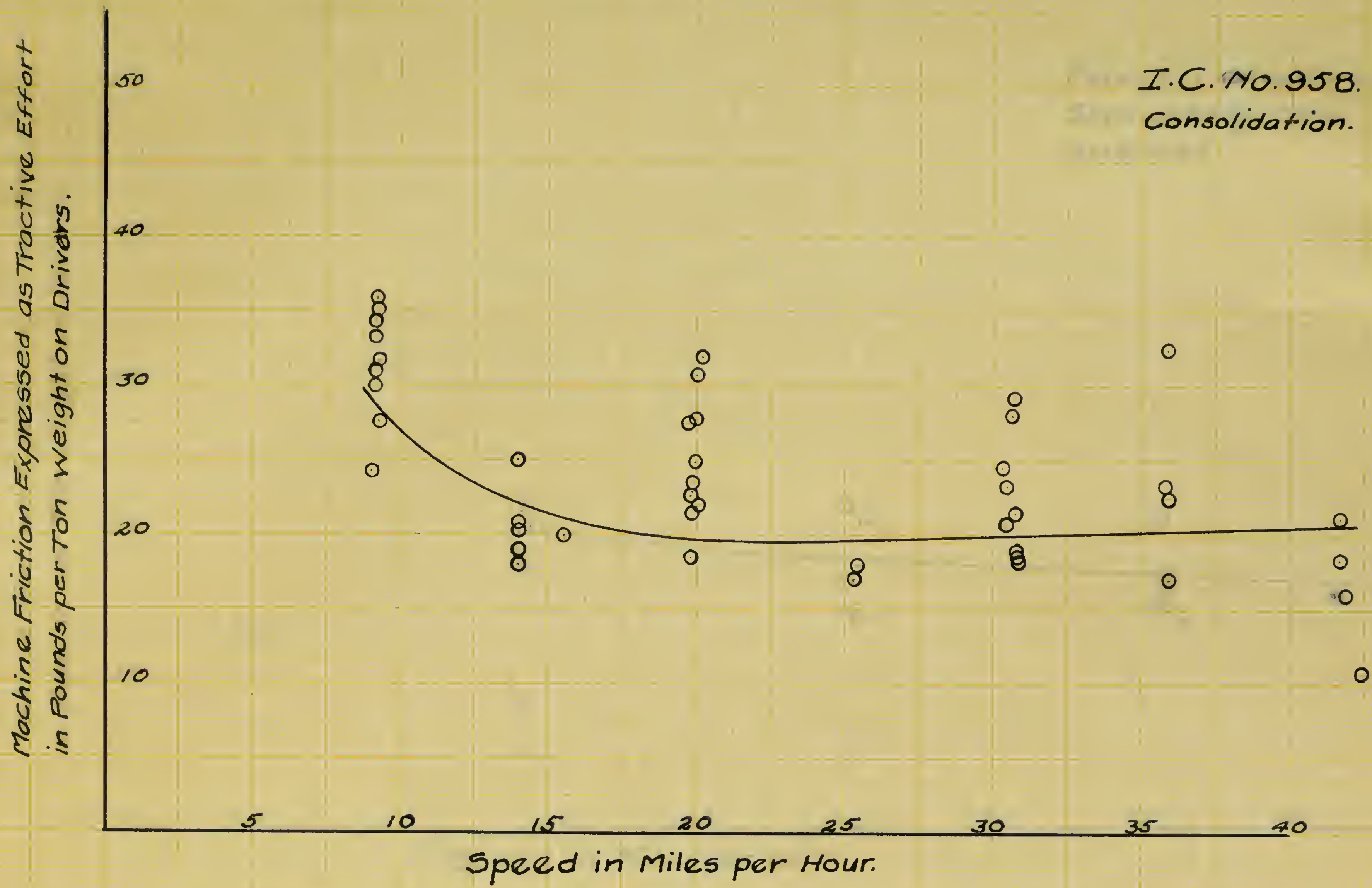


Fig. 6. Relation Between Machine Friction And Speed.

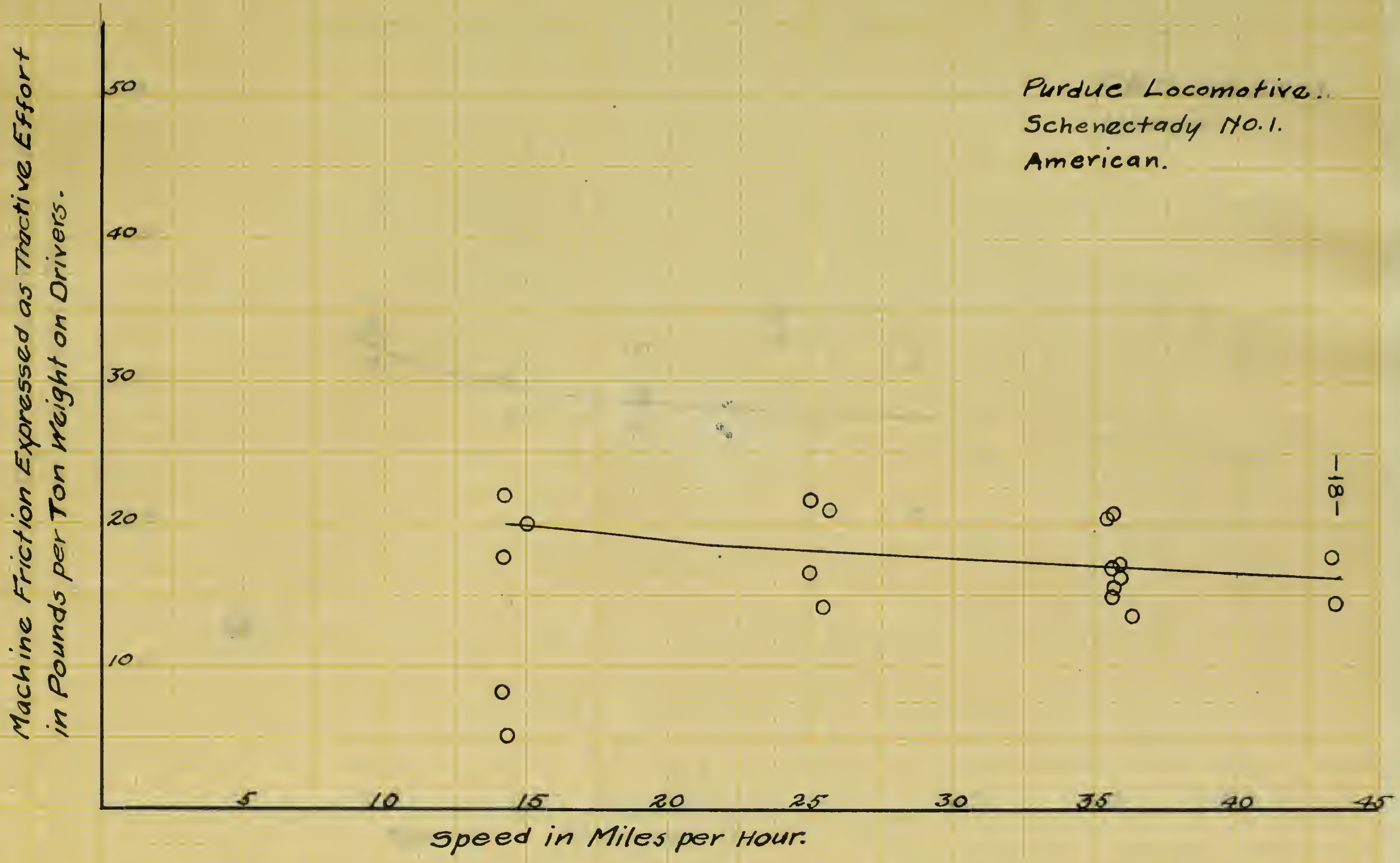


Fig. 7. Relation Between Machine Friction And Speed.

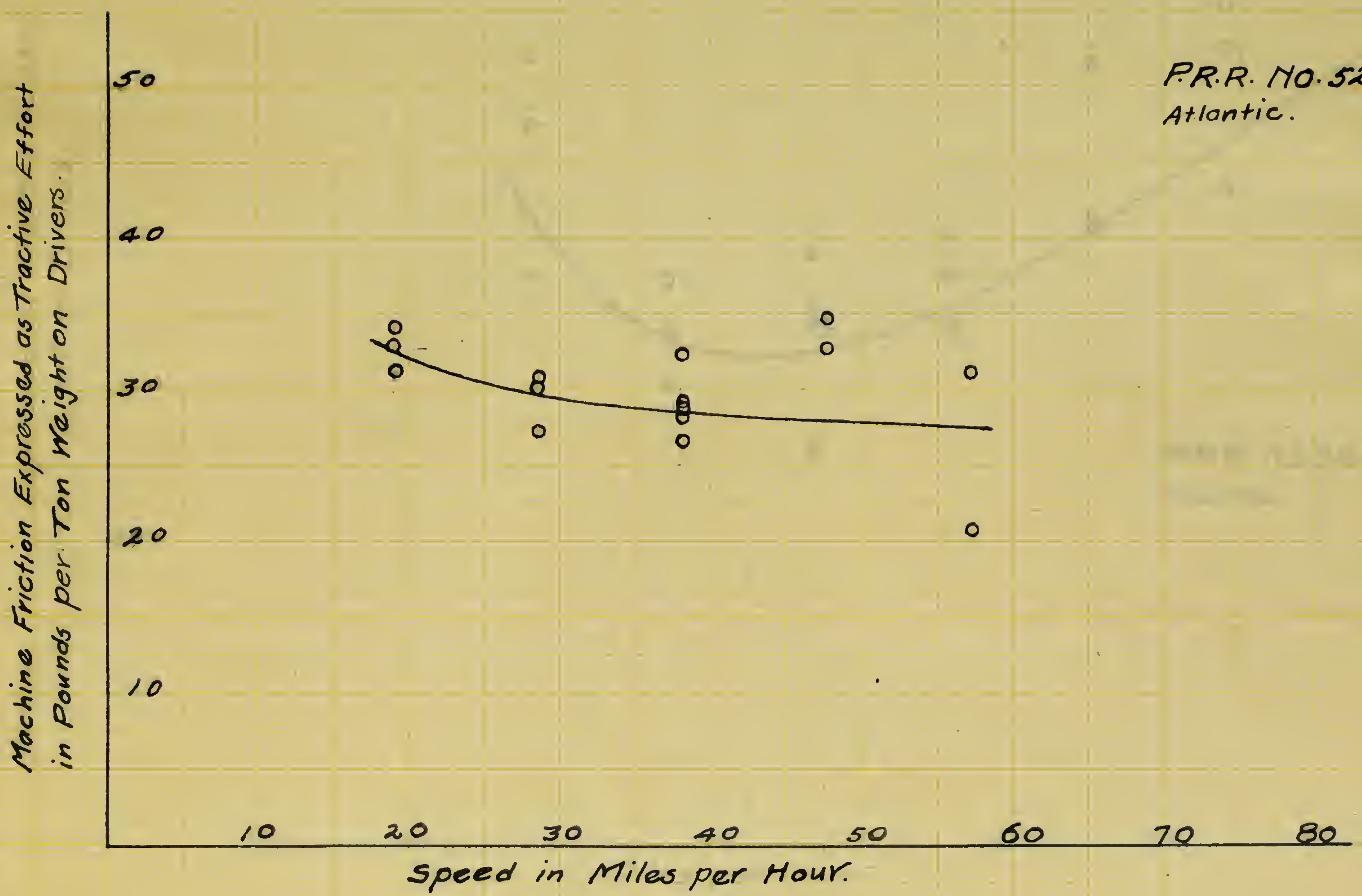


Fig. 8. Relation Between Machine Friction And Speed.

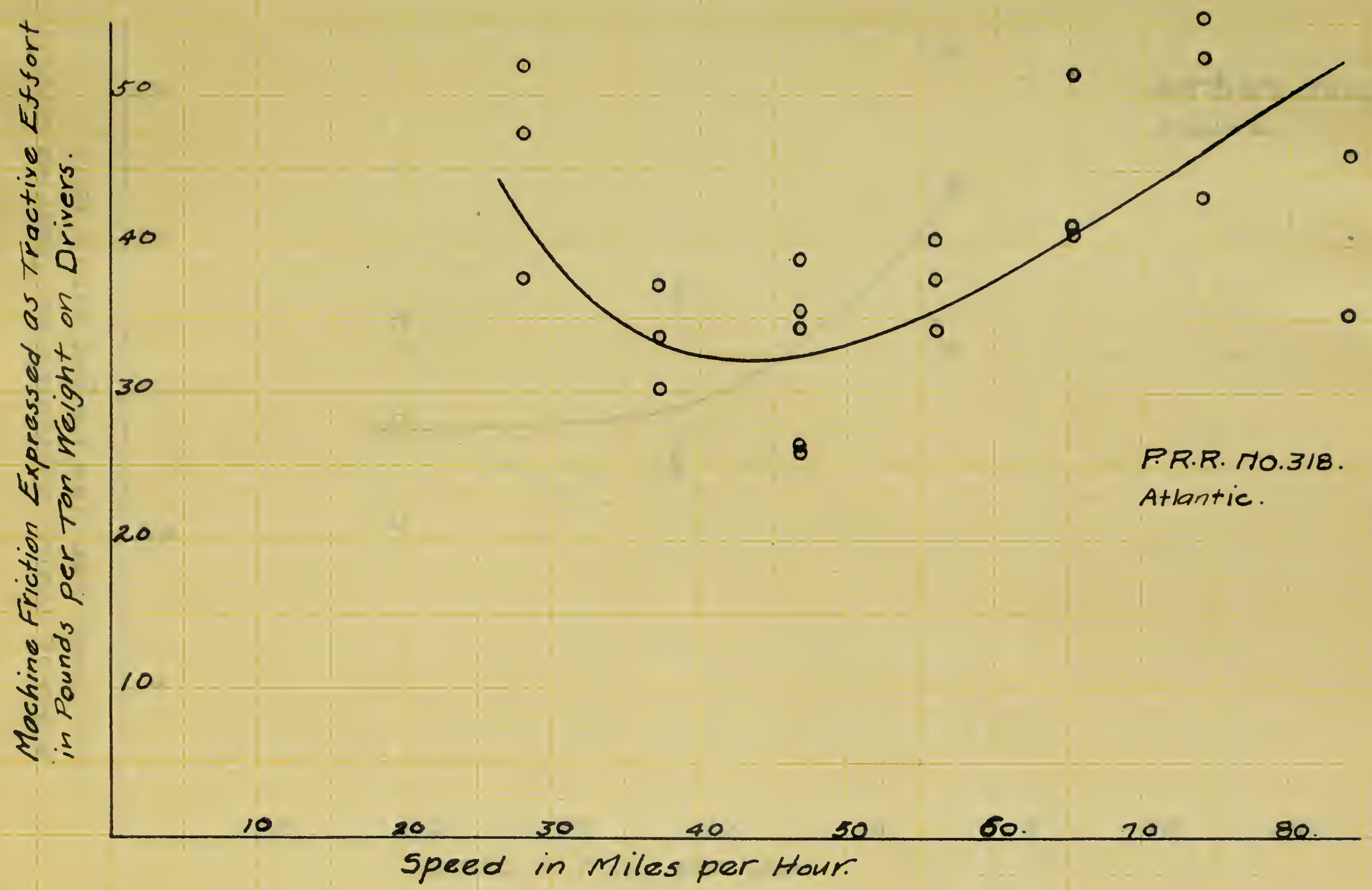


Fig. 9. Relation Between Machine Friction And Speed.

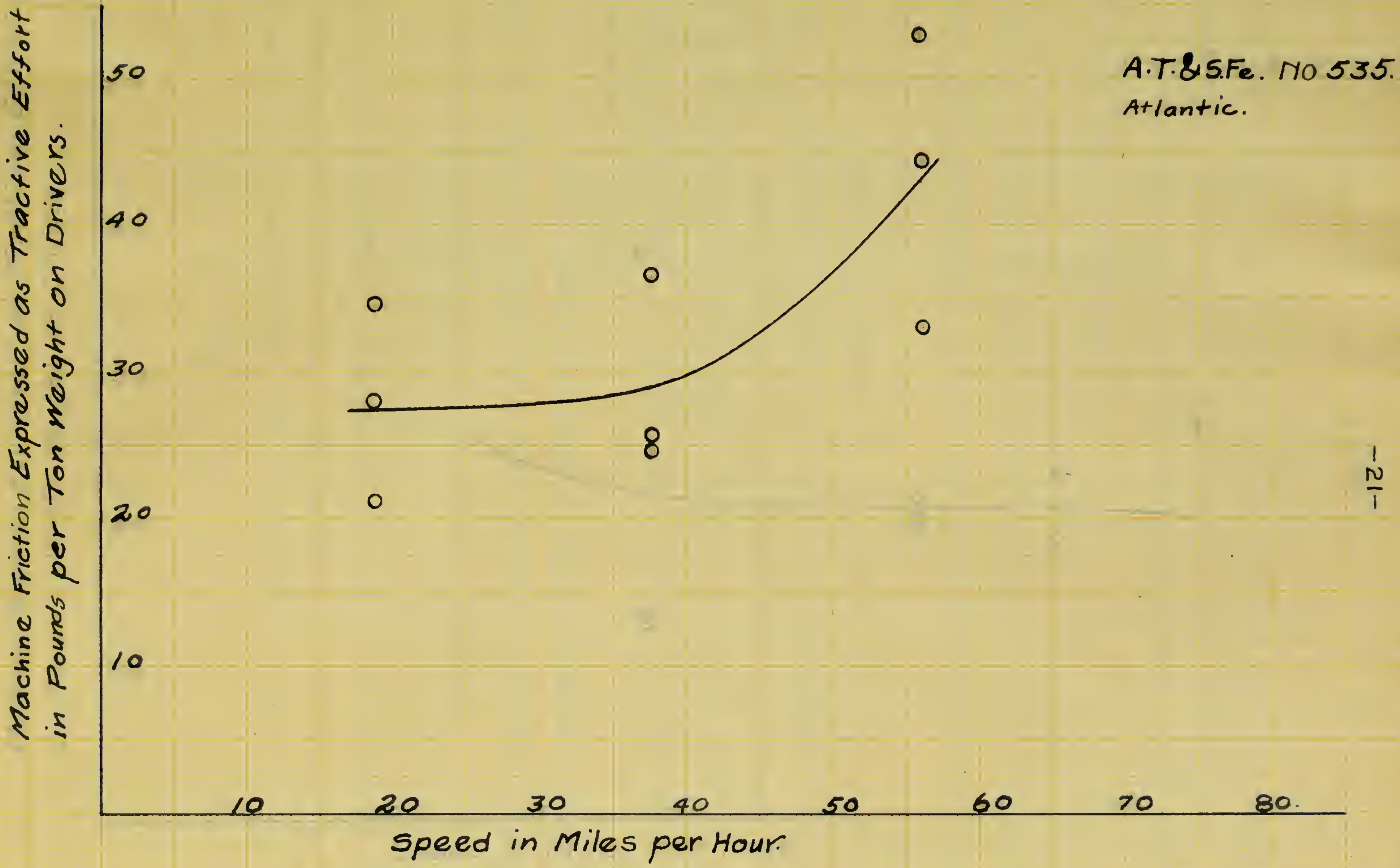


Fig. 10. Relation Between Machine Friction And Speed.

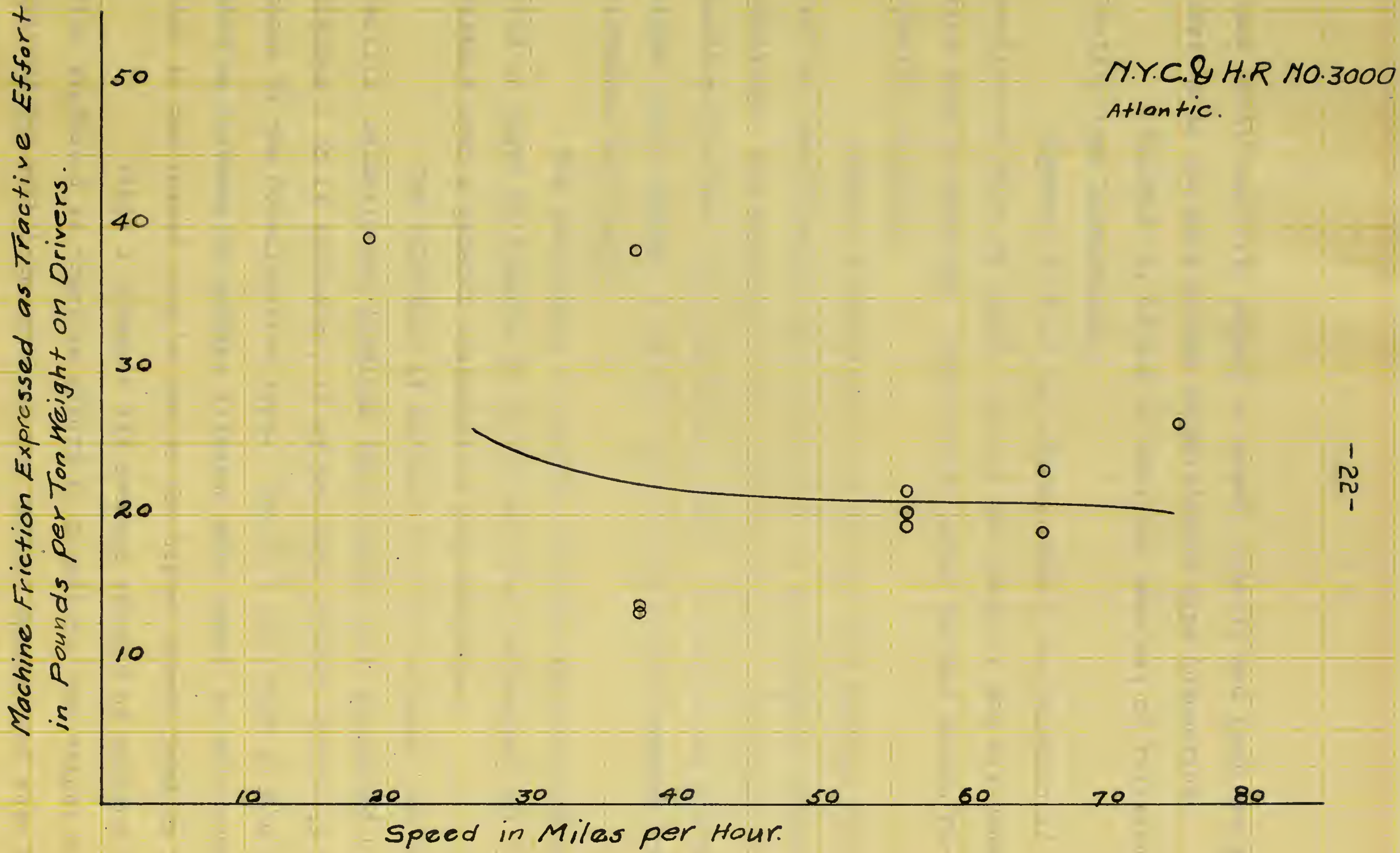


Fig. 11. Relation Between Machine Friction And Speed.

same conditions with regard to speed, cut-off and load are shown here as in the case of the Consolidation type locomotive.

Figures 12, 13 and 14 show the same set of relations for Pacific type locomotives.

Figures 15 to 17 inclusive present the relation of machine friction to speed, cut-off and load for the six Consolidation type locomotives. Each figure shows the six curves for one specific relation.

Figure 15 indicates conclusively that machine friction for the Consolidation type locomotive is an extremely variable quantity. The majority of the curves indicate a decrease of machine friction with increasing speed. In two of the six cases shown, there appears a certain speed beyond which machine friction increases with speed.

The variations of machine friction with cut-off and with load as shown by figures 16 and 17 are more pronounced and do not warrant even a general statement of the relations.

The relations of machine friction to speed for the Pacific, Atlantic and American type locomotives, presented by figures 7 to 14 inclusive, is of the same general nature as that shown by the Consolidation type. The fact that more of the curves show an increase of machine friction with speed, in this group than in the former, may be due to the higher speeds used in tests.

Table 1 presents the average results of machine friction expressed as tractive effort in pounds per ton weight on drivers for each locomotive at the various speeds used when being tested.

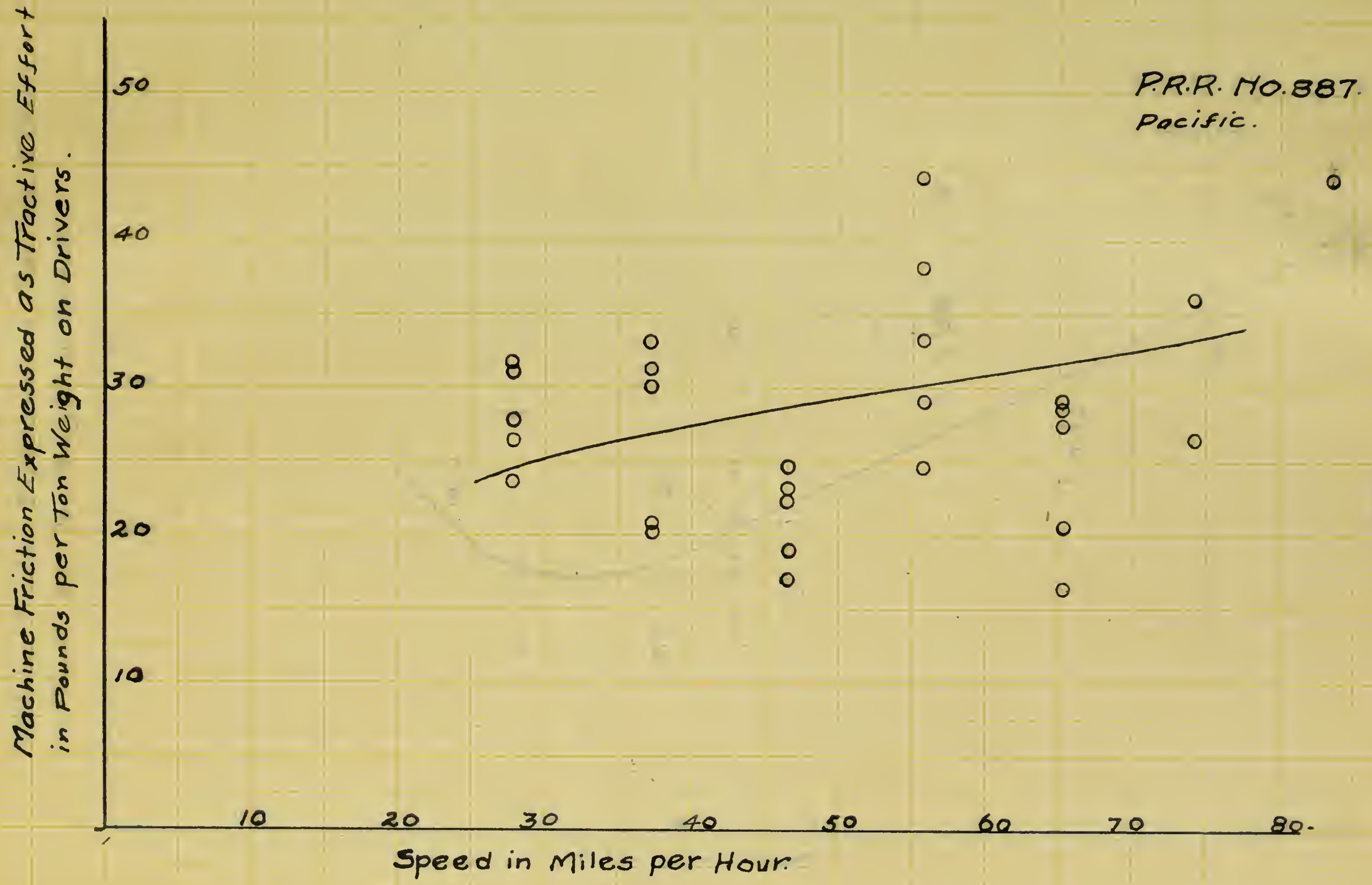


Fig. 12. Relation Between Machine Friction And Speed.

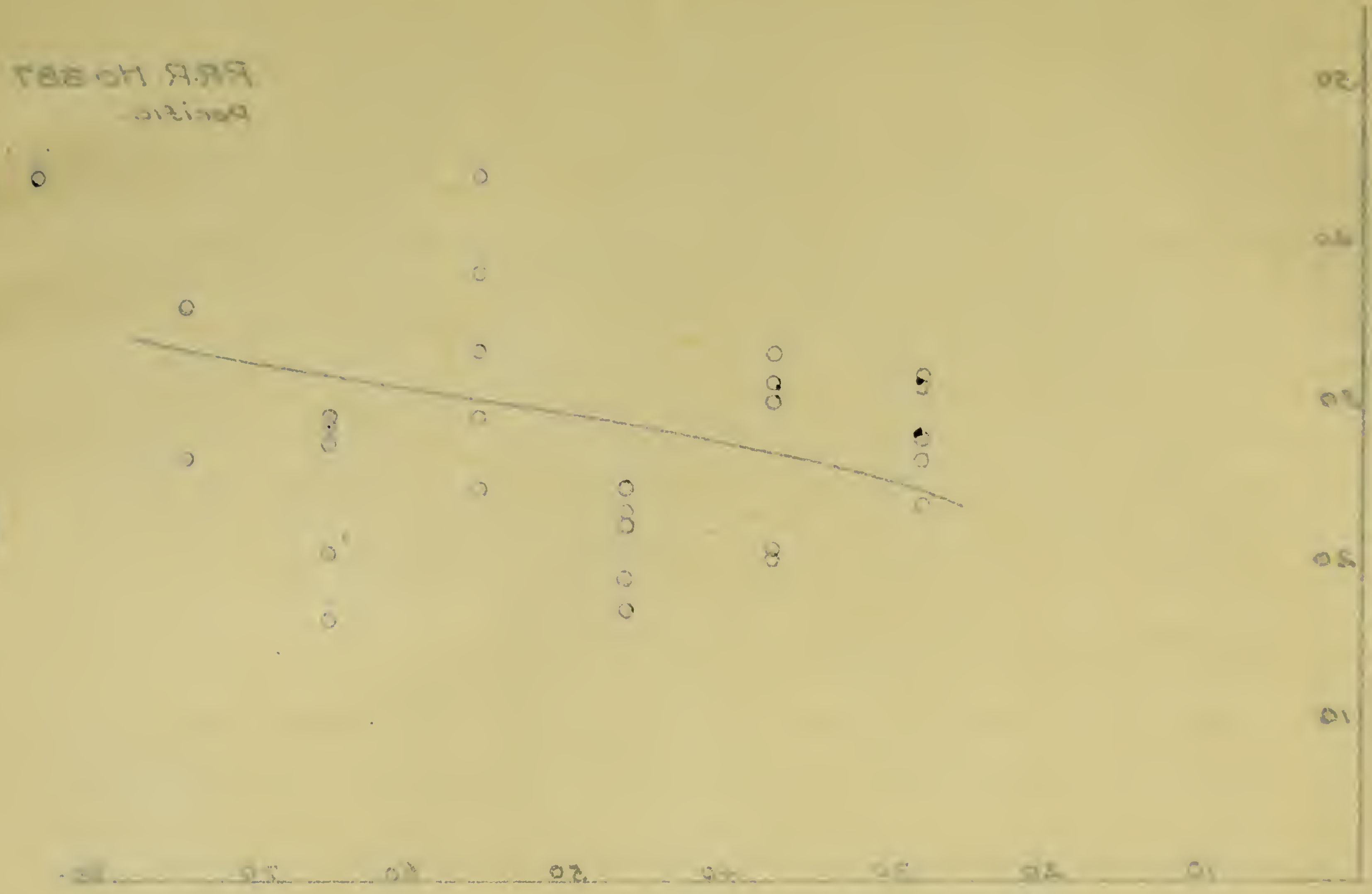


Fig 13 Relation Between Machine Friction and Speed.

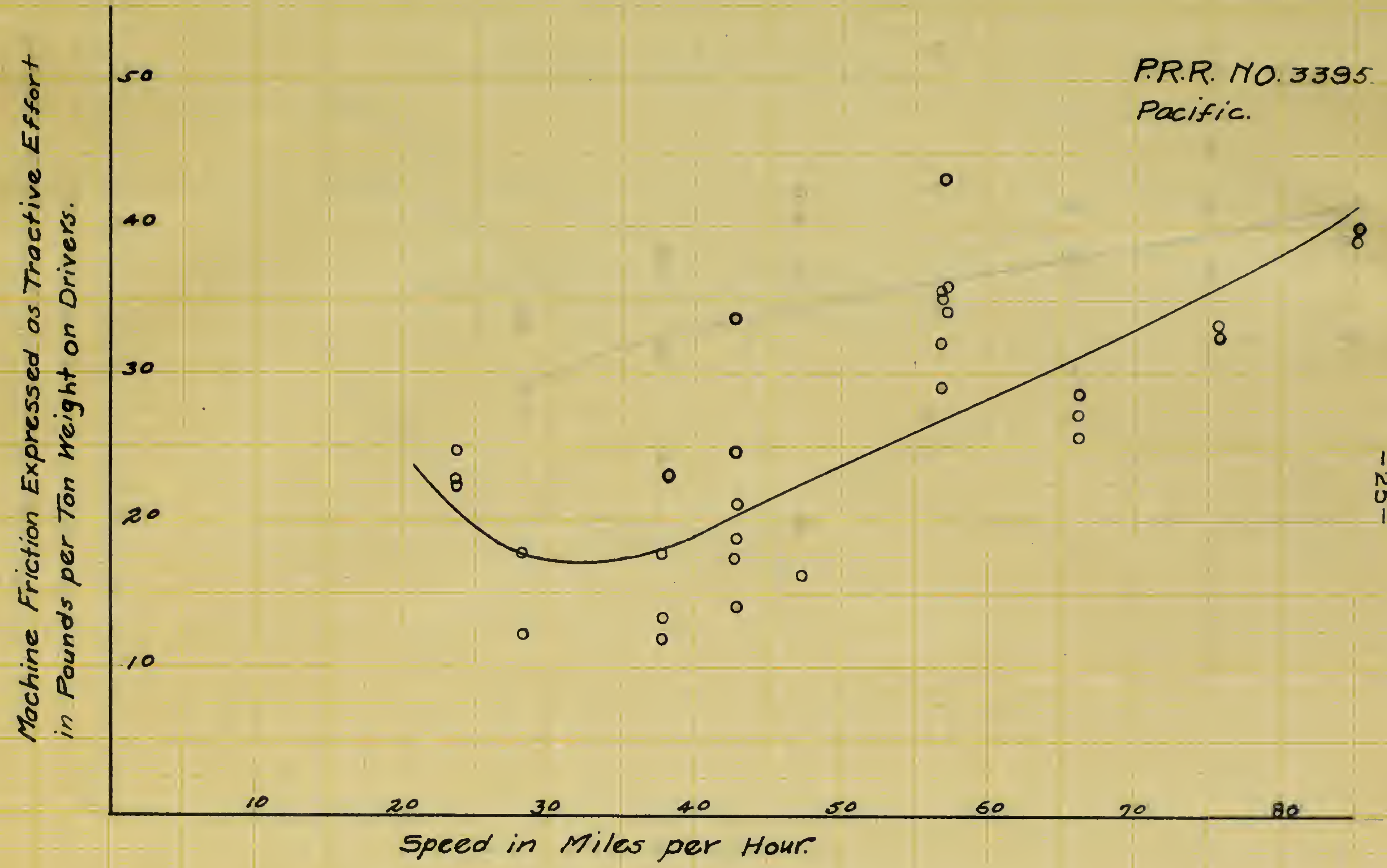


Fig. 13. Relation Between Machine Friction And Speed.

Fig. 14. Relation Between Machine Friction And Speed.

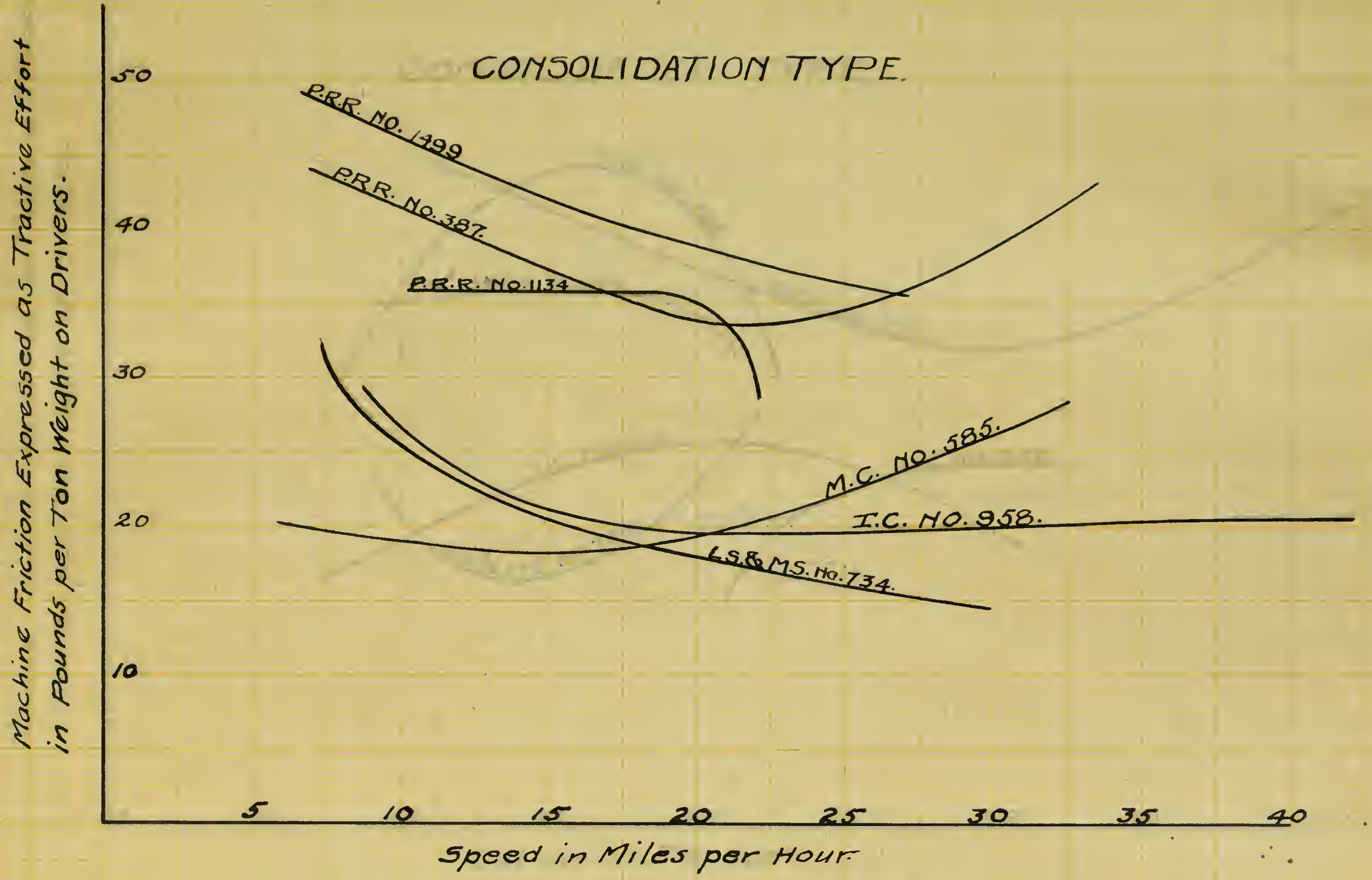
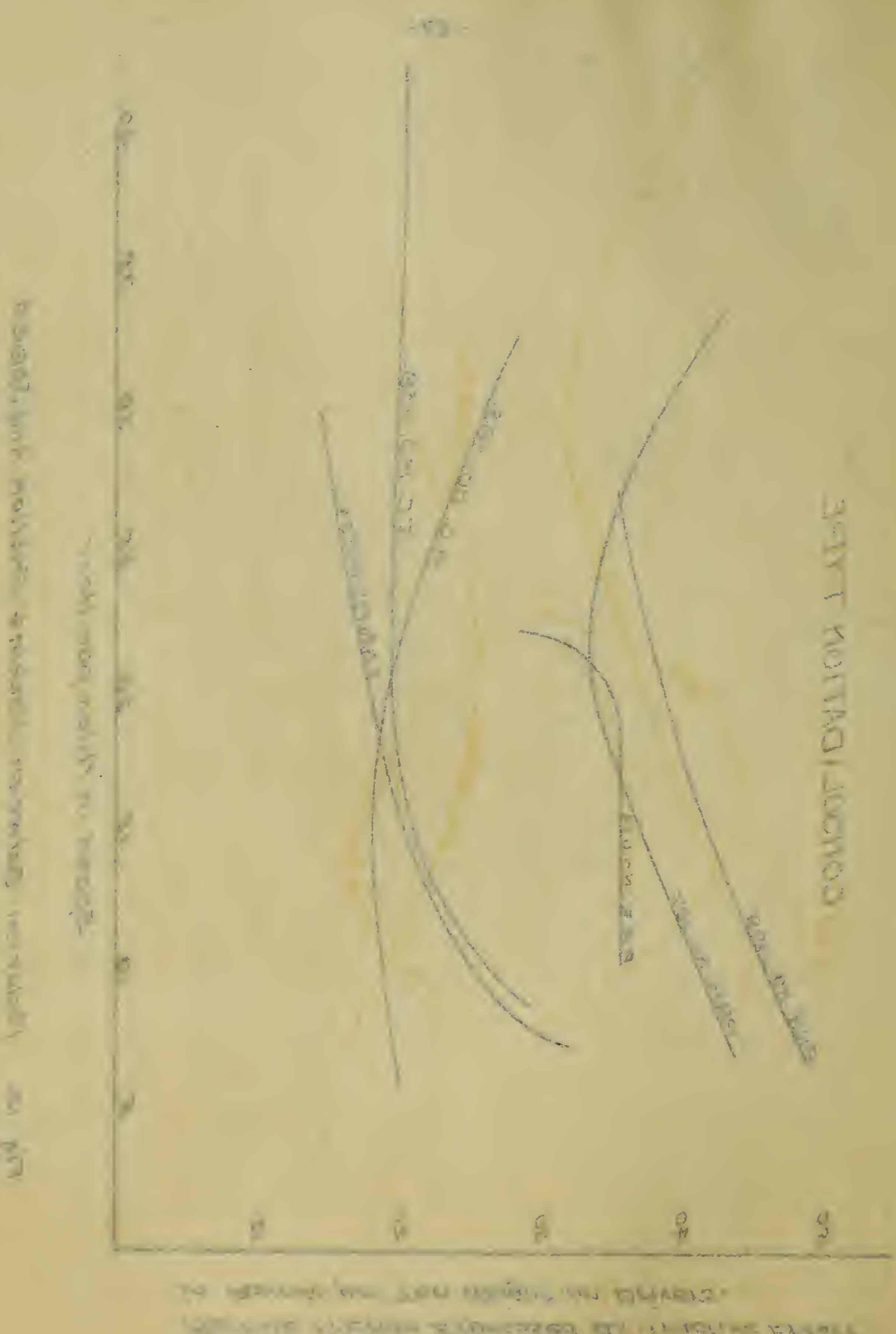


Fig. 15. Relation Between Machine Friction And Speed.



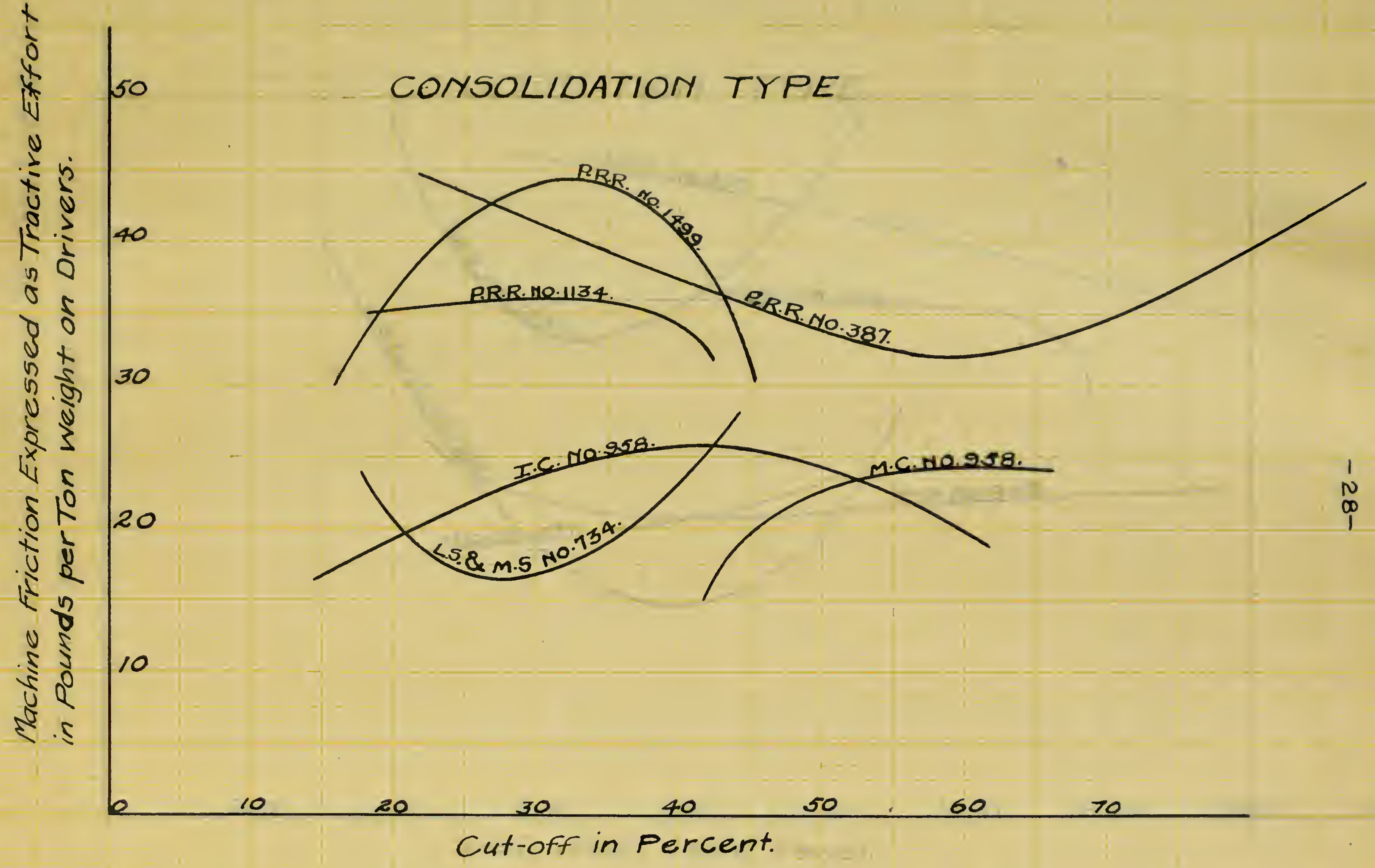
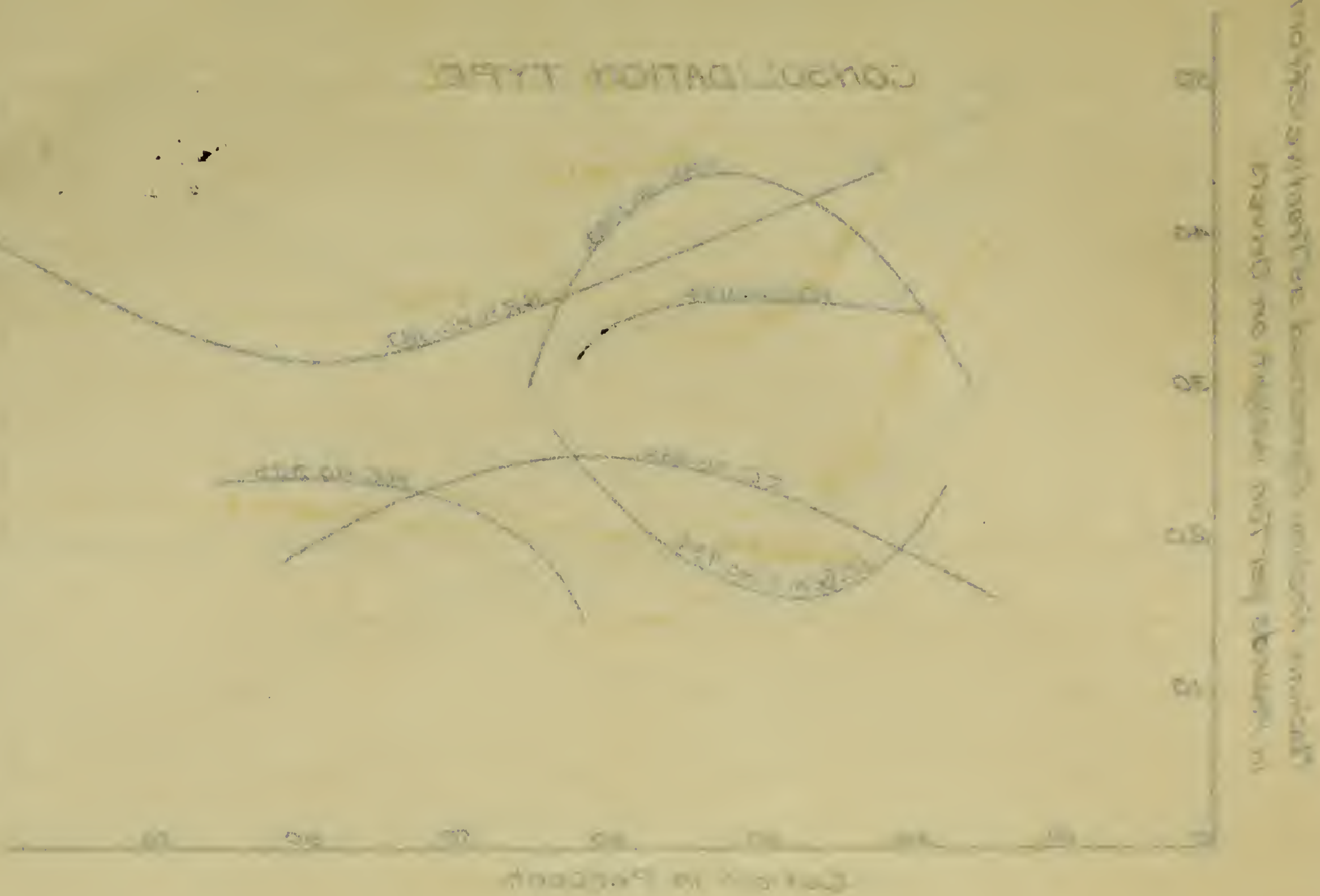


Fig. 16. Relation Between Machine Friction And Cut-off.


CONSOLIDATION TYPE
Carbon in Percent

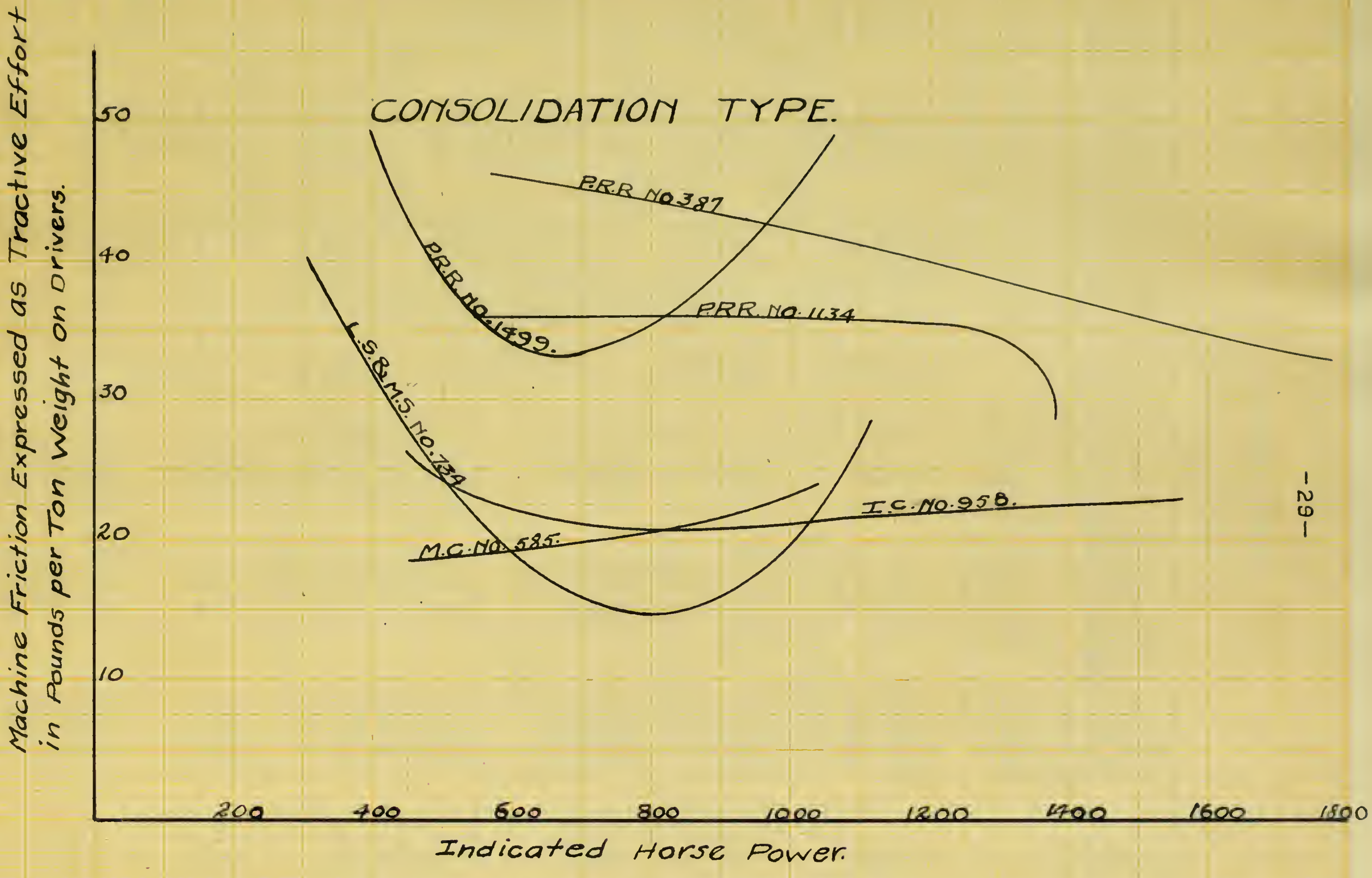


Fig. 17. Relation Between Machine Friction And Indicated Horse Power.

TABLE NO. 1.

Average Results.

Miles per hour	Machine Friction Expressed as tractive effort in pounds per ton weight on drivers.		
	Maximum	Minimum	Average
	Locomotive No. 1		
7	52.3	47.	49.6
14	52.9	34.1	43.7
20	40.5	40.5	40.5
26	44.75	27.60	35.7
	Locomotive No. 2		
7.5	40.75	19,85	30.10
15.	29.00	15.55	22.09
30.	24.15	3.32	14.50
	Locomotive No. 3		
7.5	21.40	14.00	18.00
15.00	20.50	17.95	19.00
30.00	29.80	21.58	27.62
	Locomotive No. 4		
7.	50.00	30.	43.3
10.	52.10	26.95	41.12
15	50.30	33.00	42.80
17.5	45.10	26.80	36.97
20.	39.90	29.20	33.18
25.	36.80	31.60	34.15
30.	39.60	35.10	38.04
	Locomotive No. 5.		
10.	38.40	33.6	36.00
15.	38.45	24.4	36.10
20.	28.60	28.60	32.21
	Locomotive No. 6		
10	38.40	23.35	36.00
15	25.35	18,29	20.92
20	32.40	13.90	22.00
25	18.05	17.38	17.64
30	29.40	13.78	21.74
35	32.60	17.03	24.10
40	21.25	10.95	16.71

Miles per hour	Machine Friction Expressed as tractive effort in pounds per ton weight on drivers.		
	Maximum	Minimum	Average
	Locomotive No. 7		
15	22.10	5.07	16.57
25	21.60	14.30	18.40
35	20.80	13.65	16.26
45	17.80	14.50	16.15
55	21.80	18.00	19.90
	Locomotive No. 8		
20	34.30	30.75	32.30
30	30.90	27.25	29.40
40	32.30	26.78	29.02
45	34.70	32.78	33.74
	Locomotive No. 9		
30	52.00.	37.80	45.80
35	37.40	30.80	32.94
45	35.55	26.25	32.30
55	40.40	34.25	38.16
65	51.60	40.75	44.50
75	55.40	43.40	50.50
85	46.20	35.30	40.75
	Locomotive No. 10		
20	66.75	21.33	37.72
35	36.80	24.70	29.09
55	53.00	33.00	43.48
	Locomotive No. 11		
20	65.30	39.40	52.30
35	38.50	13.20	21.80
55	21.70	19.40	20.40
65	23.20	18.75	20.97

TABLE NO. 1 (CONT'D)

Average Results.

Miles per hour	Machine Friction Expressed as tractive effort in pounds per ton weight on drivers.		
	Maximum	Minimum	Average
	Locomotive No. 12		
30	31.65	23.65	28.18
35	33.25	20.35	27.70
45	23.40	17.15	21.34
55	44.40	24.65	33.94
65	29.20	16.50	23.74
75	36.20	26.65	26.88
	Locomotive No. 13		
25	24.80	22.40	23.32
30	17.90	13.15	15.00
35	23.00	12.00	17.83
40	33.85	14.20	21.68
55	43.35	29.05	35.30
65	28.60	25.60	27,44
75	33.35	32.50	32.94
85	40.00	39.10	39.55
	Locomotive No. 14		
30	33.90	27.10	30.82
40	38.20	24.20	32.80
50	42.50	19.50	39.85
60	52.00	27.18	39.07
65	41.75	30.40	37.11
75	45.80	37.30	41.22
85	40.65	32.60	37.55

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A general conclusion based upon all of the data presented for all types of locomotives, might be that locomotive machine friction expressed as pounds of tractive effort per ton weight on drivers decreases as the speed increases. Figure 1 presenting the relation under consideration for the Consolidation type locomotive may be considered as typical in this respect.

Test conditions may have influenced the results of the two Consolidation type locomotives which disagree with this conclusion. The Michigan Central No. 585 was reported as having shown severe logitudional vibration at 30 miles per hour and this undoubtedly resulted in more rolling resistance of the drivers than would ordinarily occur.

Conclusions.

For practical purposes the expression of locomotive machine friction, as pounds of tractive effort per ton weight on drivers, in its relation to speed is the best method of exhibiting machine friction and its variations.

Locomotive machine friction, expressed in this way, in general,

1. Decreases with increasing speed.

2. Varies in rate of decrease for different types of locomotives and so far as is shown by the data at hand, is apt to vary with different locomotives of the same type.

3. Is subject to wide variations which appear to be due largely to change in operating conditions, - changes which are difficult to detect or evaluate.

Locomotive machine friction expressed as tractive effort in pounds per ton weight on drivers may in ordinary practice, vary from 15 to 50 pounds.

Table 1 presents the averages from the 14 locomotives under consideration. An arithmetical average value of all the determinations listed, all speeds being included, is 30.5 pounds of tractive effort per ton weight on drivers.

The value, 30.5 pounds of tractive effort may be considered a fair average value. This is a somewhat higher average value for locomotive machine friction than previous investigations have indicated.

APPENDIX I

Experimental Data

and

Calculated Results.

APPENDIX I.

Experimental Data and Calculated Results.

The following tables, 2 to 16 inclusive, present the experimental data that have been selected from various sources and the principal results calculated for this investigation.

Table 16 shows the principal dimensions and characteristics of the engines for which data have been selected.

The locomotives tested at St. Louis in 1904 are numbers 1, 2, 3, 10 and 11. Locomotives numbers 4, 5, 8, 9, 12, 13 and 14 were tested at Altoona, Pa., since 1904, on the test plant of the Pennsylvania Railroad. Number 6 was tested by the University of Illinois in 1914. Number 7 is the locomotive known as Schenectady Number 1. It was tested at Purdue University under the direction of Dr. W. F. M. Goss, about 1897.

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TABLE 2.

EXPERIMENTAL DATA.

Consolidation No. 734. Lake Shore & Michigan Southern Railroad

Tested at St. Louis, Mo.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	Pounds per ton weight on drivers.
201	66.87	299.4	19.15	7.56	16.03	3316	40.75
202	32.69	434.4	30.73	7.59	7.81	1616	19.85
203	58.64	550.4	41.27	7.52	14.14	2924	36.00
204	83.62	901.1	43.90	14.99	10.11	2091	25.70
205	63.78	527.0	17.32	15.09	7.67	1586	19.50
206	50.60	782.6	30.66	15.01	6.11	1264	15.55
208	67.90	962.5	40.69	14.99	8.21	1448	17.80
209	80.26	865.6	21.07	29.87	4.87	1008	13.30
210	102.88	953.7	23.32	29.98	6.22	1288	15.85
211	134.13	994.8	29.00	30.00	8.11	1677	20.60
212	157.10	1053.9	27.37	30.04	9.48	1961	24.15
* 213	85.22	886.8	39.76	30.07	5.14	1063	13.10
214	54.18	306.0	19.4	7.42	13.24	2739	33.70
215	94.43	569.0	19.7	15.02	11.40	2358	29.00
216	80.82	955.1	42.60	14.90	9.83	2034	25.00
* 217	40.11	799.5	38.50	29,85	2.44	504	6.20
* 218	21.71	865.2	39.00	30.01	1.31	271	3.32
* 219	85.99	923.4	30.95	29.77	5.24	1083	13.30
* 220	134.64	942.4	24.59	30.00	8.14	1683	20.70
* 221	140.86	1098.2	35.70	22.28	11.46	2369	29.10
* 222	98.28	1097.6	37.50	22.38	7.96	1647	20.25

* Throttle partly closed.

TABLE NO. 3

EXPERIMENTAL DATA.

Consolidation (Compound) No. 585. Michigan Central Railroad.

Tested at St. Louis, Mo.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Machine Friction Expressed as Drawbar Pull. pounds	Machine Friction Expressed as Pounds per ton weight on drivers.
301	30.98	442.5	43.1	7.49		1551	14.00
302	35.22	477.4	45.3	7.49		1764	21.40
303	30.43	512.0	48.6	7.49		1523	18.50
305	67.33	840.6	45.7	14.96		1686	20.50
306	59.21	734.9	42.2	15.01		1478	17.95
308	60.80	932.2	52.8	14.98		1522	18.50
309	60.71	1040.7	57.7	14.98		1520	18.49
311	97.38	998.2	50.6	22.09		1653	20.10
312	160.02	890.1	49.6	29.97		2003	24.30
313	168.02	991.6	50.7	29.97		2103	25.59
316	141.65	1001.3	64.3	29.96		1773	21.58
317	183.35	910.4	51.3	29.96		2296	27.65
318	176.26	937.3	60.3	29.97		2206	26.80

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TABLE NO. 4

EXPERIMENTAL DATA.

Consolidation No. 387. Pennsylvania Railroad.

Tested at Altoona, Pa.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	Pounds per ton weight on drivers.
3207	97.8	412.9	20.7	7.22	17.89	5081	46.2
3210	105.3	577.3	31.9	7.19	19.26	5495	50.0
3246	99.1	977.9	74.8	7.19	18.13	5171	47.1
3247	63.3	1019.0	88.0	7.19	11.58	3303	30.0
3205	130.9	599.2	12.19	10.83	15.96	4534	41.3
3206	127.6	579.5	22.0	10.83	15.56	4419	40.2
3209	164.6	842.5	33.0	10.78	20.07	5726	52.1
3227	139.4	899.4	35.3	10.78	17.00	4849	44.0
3242	134.1	1336.6	69.3	10.78	16.35	4665	42.5
3245	132.1	1364.3	74.8	10.78	16.11	4596	41.8
3244	85.1	1358.1	86.3	10.78	10.38	2960	26.95
3201	192.6	733.5	23.8	14.44	17.61	5003	45.4
3202	176.4	1050.1	34.6	14.44	16.13	4582	41.7
3203	201.9	1262.9	42.1	14.44	18.46	5245	47.6
3204	172.5	1252.4	42.8	14.44	15.78	4481	40.75
3238	171.7	1469.0	51.8	14.38	15.70	4480	40.75
3239	146.5	1560.7	57.6	14.38	13.40	3622	33.00
3241	212.0	1649.4	63.4	14.38	19.39	5531	50.30
3208	233.5	1131.9	31.3	18.05	17.08	4852	44.20

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TABLE NO. 4 (CONT'D).

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	Pounds per ton weight on drivers
3211	242.0	1138.5	30.9	17.97	17.71	5051	46.00
3212	188.6	1129.0	30.5	17.97	13.80	3937	35.80
3213	237.5	1478.4	42.6	17.97	17.38	4957	45.10
3214	183.6	1432.9	41.6	17.97	13.43	3832	34.80
3215	182.2	1547.5	45.4	17.97	13.33	3803	34.60
3236	140.4	1657.0	50.1	17.97	10.27	2931	26.65
3237	141.8	1729.6	52.6	17.97	10.37	2949	26.80
3233	186.7	957.5	23.7	21.56	11.38	3247	29.6
3221	252.1	1394.2	33.9	21.56	15.37	4385	39.9
3230	209.1	1632.2	41.7	21.56	12.75	3621	32.95
3216	190.1	1677.5	50.5	21.56	11.59	3307	30.10
3217	213.4	1783.1	50.3	21.56	13.01	3712	33.78
3225	271.5	1341.6	29.5	25.16	14.19	4048	36.80
3218	232.6	1528.8	37.5	25.16	12.16	3468	31.60
3230	250.9	1786.3	41.5	25.16	13.11	3741	34.05
3229	330.2	1610.4	34.1	28.75	15.10	4289	39.00
3222	312.6	1738.1	37.9	28.75	14.29	4078	37.10
3235	295.9	1829.9	42.3	28.75	13.53	3860	35.10
3228	352.2	1147.6	22.4	30.50	15.16	4324	39.40
3224	354.4	1813.4	38.6	30.50	15.25	4351	39.60

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TABLE NO. 5.

EXPERIMENTAL DATA.

Consolidation No. 1134. Pennsylvania Railroad.

Tested at Altoona, Pa.

Test Number	Horse-Power		Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as		
	Friction	Indicated			M. e. p. pounds	Drawbar Pull. pounds	Pounds per ton weight on drivers
2770	118.9	531.65	19.25	11.00		4054	38.4
2775	103.9	535.66	20.50	11.00		3545	33.6
2771	156.1	846.36	27.40	14.66		3992	37.8
2776	141.7	856.61	29.20	14.66		3624	34.4
2772	139.4	1018.49	35.80	14.66		3565	33.8
2777	158.7	1032.28	35.00	14.66		4059	38.45
2773	183.8	1234.11	45.30	18.33		3760	35.65
2778	185.4	1288.73	44.20	18.33		3793	36.00
2774	177.3	1364.64	40.30	22.00		3023	28.60
2779	177.6	1423.31	38.80	22.00		30.28	28.61
					Not given in report		

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TABLE NO. 6.

EXPERIMENTAL DATA.

Consolidation No. 958. Illinois Central Railroad.

Tested at University of Illinois.
(Series I)

Test Number.	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	Pounds per ton weight on drivers.
2009	--	345.5	17.1	25.2	---	---	---
2010	--	373.9	19.2	35.7	---	---	---
2012	117.9	802.8	23.3	25.3	7.35	1746	17.38
2013	122.6	986.3	30.8	25.4	7.63	1812	18.05
2014	225.9	1079.0	31.4	36.3	9.86	2337	23.20
2015	219.4	845.6	22.7	36.3	9.56	2267	23.60
2016	165.6	533.8	16.4	36.3	7.22	1711	17.03
2017	71.0	428.1	16.9	14.5	7.72	1837	18.29
2018	82.1	593.8	22.6	14.5	8.93	2120	21.10
2019	82.6	765.7	30.6	14.6	8.92	2118	21.05
2020	75.5	584.4	22.4	14.6	8.16	1938	19.28
2021	82.3	428.6	14.9	14.5	8.93	2123	21.18
2022	99.3	773.9	30.3	14.6	10.71	2545	25.35
2023	118.2	1188.7	39.4	25.2	7.40	1757	17.48
2024	75.4	431.0	---	9.2	12.94	3073	30.59
2026	99.9	515.0	19.1	19.9	7.95	1887	18.78
2027	115.5	749.1	24.3	20.0	9.14	2169	21.60
2028	60.6	548.7	31.7	9.1	10.47	2489	24.80
2029	147.8	968.6	30.7	19.9	11.71	2781	27.70

TABLE NO. 6 (CONT'D)

(Intermediate Tests)

Test Number	Horse-Power Friction.	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Machine Friction Expressed as Drawbar Pull. pounds	Machine Friction Expressed as Pounds per ton weight on drivers
2030	173.8	899.6	23.4	30.8	8.93	2118	21.09
2031	84.2	953.9	39.5	15.6	8.56	2023	20.18
2032	171.8	1094.6	30.2	30.5	8.90	2112	21.00
2033	134.4	1142.3	40.7	20.0	10.64	2527	25.18
2034	315.0	1276.7	41.4	36.0	13.81	3279	32.60
2035	176.2	1119.1	39.9	20.3	13.70	3256	32.40
2037	232.4	1277.7	40.1	30.7	11.94	2836	28.20
2038	60.0	428.4	---	9.2	10.28	2440	23.35
2039	115.8	940.0	32.5	20.0	9.17	2175	21.80
2040	117.4	1251.0	41.5	30.7	6.05	1437	13.78
2041	102.7	1110.4	41.1	20.0	8.11	1923	18.40
2042	78.9	753.9	24.8	20.0	6.27	1483	14.20
2043	101.1	1259.6	48.5	19.9	8.02	1903	18.20
2044	77.0	1334.7	57.5	19.9	6.10	1449	13.90
2045	82.5	519.1	19.2	19.9	6.53	1551	14.85

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TABLE NO. 6 (CONT'D)

EXPERIMENTAL DATA.

Concolidation No. 958. Illinois Central Railroad.

Tested at University of Illinois.
(Series II)

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	Pounds per ton weight on drivers
2072	126.0	1233.8	41.5	19.9	9.97	2375	23.60
2073	121.0	1019.3	29.6	19.9	9.59	2284	22.75
2074	157.0	1264.3	28.8	30.8	8.04	1913	19.05
2075	77.0	578.6	32.1	9.2	13.20	3154	31.40
2076	207.2	1364.2	32.2	41.7	7.81	1861	18.55
2077	125.5	795.7	24.0	20.1	9.83	2342	23.30
2078	177.4	1011.2	24.0	30.7	9.10	2169	21.60
2079	181.4	1109.9	23.4	42.1	6.78	1615	16.09
2080	---	558.5	16.9	20.0	--	---	---
2081	---	450.5	24.1	9.2	---	---	---
2082	242.7	1457.3	41.4	30.8	12.40	2954.	29.4
2083	146.8	730.4	18.4	30.9	7.46	1780	17.7
2084	150.3	1347.5	48.4	30.0	11.79	2813	28.0
2085	79.8	694.3	41.3	9.3	13.54	3224	32.1
2086	70.0	456.0	23.4	9.3	11.83	2817	28.0
2087	122.7	560.3	16.6	20.2	9.57	2280	22.7
2088	124.8	756.1	15.9	42.5	4.64	1101	10.95
2089	238.3	1559.9	43.5	41.9	8.97	2134	21.25
2092	149.7	1267.3	30.4	30.6	7.71	1834	18,35
2093	201.9	1633.5	48.6	30.4	10.41	2491	24.80

TABLE NO.6 (CONT'D)

(Series II)

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	Pounds per ton weight on drivers.
3094	167.3	1521.4	57.0	20.1	13.10	3117	31.00
3095	86.9	804.9	49.2	9.3	14.62	3501	34.85
3096	90.8	713.6	40.4	9.4	15.28	3641	36.20
3097	85.4	610.6	33.3	9.5	14.20	3385	33.70
3098	90.0	823.2	49.1	9.4	15.06	3592	35.78
3090	128.2	743.1	23.8	20.7	10.02	2394	23.98
3091	154.4	1140.0	28.8	30.7	7.89	1884	18.05

TABLE NO. 7.

EXPERIMENTAL DATA.

Schenectady No. 1.

Tested at Purdue University.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull pounds	Pounds per ton weight on drivers
1	23.6	198.1	14.35	25	5.66	619	22.1
2	22.5	185.7	15.04	25	5.13	561	20.0
3	40.6	285.0	25.16	25	5.53	605	21.6
4	40.2	285.6	25.70	25	5.40	587	21.0
5	55.4	357.8	35.64	25	5.33	582	20.8
6	54.3	321.3	35.47	25	5.24	574	20.5
7	61.9	371.4	46.68	25	4.49	497	17.8
8	92.2	396.1	56.83	25	5.57	610	21.8
9	13.8	254.4	14.29	35	4.50	492	17.6
10	31.3	371.4	24.99	35	4.28	469	16.7
11	43.4	460.0	35.96	35	4.14	453	16.4
12	50.3	495.6	46.48	35	3.71	406	14.5
13	78.0	497.1	58.06	35	4.61	504	18.0
14	27.1	495.9	25.48	45	3.66	400	14.3
15	37.6	582.0	36.70	45	3.48	381	13.65
16	5.5	290.1	14.38	80	1.30	142	5.07
17	8.9	266.6	14.17	80	2.08	227	8.10
18	40.0	373.9	35.61	35	3.84	420	15.00
19	41.4	358.0	35.66	35	3.98	435	15.50
20	46.2	327.5	35.88	35	4.41	483	17.25
21	45.2	245.1	35.59	35	4.35	476	17.00

TABLE NO. 8.

EXPERIMENTAL DATA.

Atlantic type Locomotive No. 5366. Pennsylvania Railroad.

Tested at Altoona, Pa.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Machine Friction Expressed as Drawbar Pull pounds	Machine Friction Expressed as Pounds per ton weight on drivers
901	92.5	419.8	15.7	19.10	13.34	1816	33.
902	87.4	477.2	17.9	19.10	12.57	1716	31.2
904	86.0	585.6	23.7	19.09	12.40	1689	30.75
906	95.6	727.9	29.7	19.01	12.78	1886	34.30
908	131.4	687.6	18.8	28,65	12.63	1652	30.05
910	130.1	851.1	24.9	28.65	12.50	1702	30.90
912	114.6	1015.4	31.7	28.65	11.01	1499	27.25
913	180.6	748.8	16.7	38.20	13.01	1417	26.78
914	160.9	826.8	20.2	38.20	11.60	1579	28.70
916	180.9	1011.6	24.9	38.20	13.03	1775	32.30
917	162.9	1055.0	27.7	38.20	11.74	1599	29.10
918	158.4	1133.4	31.5	38.20	11.41	1554	28.30
920	229.2	1018.6	19.5	47.75	13.21	1805	32.78
922	243.1	1223.7	25.5	47.75	14.01	1909	34.70
923	204.7	1085.4	19.0	57.30	8.43	1148	20.80
924	261.7	1164.5	21.6	57.30	12.57	1713	31.20
927	331.2	1178.4	19.9	66.85	13.64	1856	33.70
929	384.4	1281.3	31.4	76.08	---	---	---

TABLE NO. 9

EXPERIMENTAL DATA.

Atlantic Type Locomotive No. 318. Pennsylvania Railroad.

Tested at Altoona, Pa.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Machine Friction Expressed as Drawbar Pull. pounds	Machine Friction Expressed as pounds per ton weight on drivers
3111	248.2	746.8	18.3	28.01	20.84	3324	52.0
3112	235.5	945.1	25.2	28.01	19.74	3140	47.5
3137	180.5	1129.1	34.4	28.01	15.20	2417	37.8
3121	192.5	1161.4	26.4	37.34	12.16	1933	30.7
3113	216.1	1193.9	31.5	37.34	13.65	2170	33.95
3114	237.6	1313.8	41.1	37.34	15.00	2586	37.40
3133	192.2	1315.6	42.8	37.34	12.14	1930	30.20
3136	307.2	1534.2	21.2	46.68	10.47	1665	26.05
3115	310.1	1548.9	32.7	46.68	15.66	2492	39.00
3134	273.3	1574.8	31.5	46.68	13.81	1690	26.45
3135	235.2	1588.2	31.1	46.68	11.88	2196	34.38
3124	282.6	1596.1	41.5	46.68	14.28	2271	35.55
3117	358.4	1624.03	22.8	66.02	15.09	2400	37.60
3116	385.5	1690.5	33.4	56.02	16.23	2581	40.40
3109	327.4	1691.6	42.1	56.02	13.78	2192	34.25
3139	384.9	1724.4	41.9	56.02	16.20	2581	40.40
3119	575.3	1738.9	25.7	65.35	20.76	3302	51.60
3122	455.1	1776.9	31.1	65.35	16.42	2612	40.75
3125	458.5	1820.6	34.4	65.35	16.54	2631	41.20

TABLE NO. 9 (CONT'D)

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar pull pounds	pounds per ton weight on drivers
3136	704.0	1853.0	21.2	74.69	22.23	3535	55.40
3128	551.1	1854.7	25.8	74.69	17.40	2768	43.40
3127	669.6	1858.4	30.8	74.69	21.14	3363	52.60
3142	505.4	1861.8	31.2	84.02	14.18	2256	35.30
3143	662.1	1958.5	31.6	84.02	18.56	2956	46.20

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TABLE NO. 10

EXPERIMENTAL DATA.

Atlantic Type Locomotive No. 535.
Vauclain Compound.

Atchison, Topeka and
Sante Fe Railroad.

Tested at St. Louis, Mo.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Machine Friction Expressed as Drawbar pull. pounds	Machine Friction Expressed as Pounds per ton weight on drivers
601	52.69	356.2	26.7	18.79		1057	21.33
602	85.77	479.0	31.0	18.79		1720	34.70
603	69.37	570.4	37.6	18.79		1391	28.10
604	166.10	808.4	53.0	18.79		3309	66.75
605	122.06	877.1	36.1	37.59		1224	24.70
606	127.15	999.9	43.0	37.59		1275	25.77
607	181.69	1296.1	50.5	37.59		1822	36.80
609	392.31	1414.6	46.4	56.35		2623	53.00
610	244.79	1549.4	51.3	56.35		1636	33.00
611	351.66	1621.5	52.9	56.38		2350	44.45
613	561.65	1459.7	47.7	65.77		3218	64.9

Not reported
in test data.

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TABLE NO. 11

EXPERIMENTAL DATA.

Atlantic Type Locomotive No. 3000.
Balanced Compound.

New York City and Hudson
River Railroad.

Tested at St. Louis, Mo.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar pull. pounds	pounds per ton weight on drivers
801	178.91	567.4	36.0	18.72		3585	65.3
802	107.97	714.4	45.9	18.76		2159	39.4
805	72.44	967.0	36.3	37.52		724	13.2
806	75.73	1253.0	43.7	37.52		757	13.8
807	211.73	1490.5	57.1	37.52		2116	38.5
809	178.85	1142.8	32.2	56.29		1192	21.7
811	159.71	1629.8	46.6	56.28		1064	19.4
812	165.88	1641.4	53.7	56.29		1105	20.1
813	223.44	1192.3	32.2	65.69		1276	23.2
814	180.36	1368.9	38.2	65.66		1030	18.75
815	290.28	1335.7	41.0	75.05		1450	26.40

TABLE NO. 12

EXPERIMENTAL DATA

Pacific Type Locomotive No. 877. Pennsylvania Railroad.

Tested at Altoona, Pa.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar pull. pounds	pounds per ton weight on drivers
3008	211.7	931.49	20.1	27.91	15.18	2844	31.65
3001	208.4	972.22	21.4	27.98	14.94	2793	31.10
3002	177.6	1129.60	28.4	27.98	12.74	2380	26.50
3003	187.8	1448.30	39.6	27.98	13.47	2517	38.00
3004	158.5	1463.60	40.6	27.98	11.37	2124	23.65
3005	297.3	1239.76	23.3	37.31	15.99	2988	33.25
3006	270.0	1441.30	30.2	37.31	14.52	2713	30.20
3007	281.0	1663.80	35.2	37.31	15.11	2824	31.45
3009	277.1	1624.40	33.4	37.22	14.90	2792	30.10
3027	185.1	1984.50	44.9	37.22	9.96	1865	20.80
3029	181.4	2047.80	49.3	37.22	9.76	1828	20.35
3010	275.6	1430.60	22.7	46.52	11.86	2221	24.78
3028	211.5	1687.40	29.6	46.52	9.10	1705	19.00
3011	191.2	1908.70	33.8	46.52	8.23	1541	17.15
3016	261.3	2270.00	50.0	46.52	11.24	2106	23.40
3017	250.2	2339.70	50.9	46.52	10.76	2017	22.40
3023	446.7	1634.30	24.8	55.82	16.02	3001	33.40
3012	510.8	1910.00	28.0	55.82	19.07	3431	38.20
3021	389.1	2073.10	33.9	55.82	13.95	2614	29.05

TABLE NO. 12 (CONT'D)

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar pull. pounds	pounds per ton weight on drivers
3013	584.1	2160.50	36.3	55.82	21.30	3991	44.40
3020	330.1	2411.00	50.4	55.82	11.84	2218	24.65
3025	253.6	1839.80	24.8	65.13	7.79	1460	16.50
3014	322.3	2104.00	29.8	65.13	9.91	1856	20.65
3026	447.2	2258.62	35.4	65.13	13.74	2575	28.60
3015	456.0	2399.90	35.7	65.13	14.01	2625	29.20
3024	490.4	2033.10	23.5	74.43	13.19	2471	27.50
3019	475.3	2290.30	30.6	74.43	12.78	2394	26.65
3022	646.4	2457.30	35.1	74.43	17.38	3256	36.20
3030	890.6	2576.20	38.5	83.74	21.29	3988	44.45

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TABLE NO. 13

EXPERIMENTAL DATA

Pacific Type Locomotive No. 3395. Pennsylvania Railroad.

Tested at Altoona, Pa.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar pull. pounds	pounds per ton weight on drivers
2449	154.6	950.9	20.8	23.66	9.72	2450	24.80
2459	139.5	933.7	18.4	23.66	8.77	2212	22.40
2434	141.7	944.0	20.2	23.66	8.91	2246	22.78
2409	---	---	---	23.76	---	--	---
2410	---	---	---	23.76	---	---	---
2435	133.9	1385.6	28.1	28.39	7.02	1769	17.90
2450	90.8	1385.6	28.6	28.39	4.76	1199	12.15
2414	230.1	1833.5	31.7	38.20	9.04	2270	23.00
2416	229.8	1840.7	31.6	38.20	9.01	2261	22.90
2420	---	---	---	38.20	---	---	---
2436	177.2	1762.5	33.1	37.86	6.97	1755	17.75
2453	120.0	1789.1	31.1	37.86	4.72	1189	12.00
2457	134.7	1762.0	31.6	37.86	5.29	1334	13.51
2413	381.3	1978.3	29.2	42.77	13.52	3343	33.85
2422	277.3	2246.5	39.4	42.77	---	2431	24.60
2438	196.1	2242.5	41.1	42.59	6.85	1727	17.49
2437	236.5	2269.1	42.5	42.59	8.26	2083	21.10
2426	---	---	---	42.77	---	---	---
2451	311.6	2372.0	46.0	42.59	7.39	1863	18.85

TABLE NO. 13 (CONT'D)

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	pounds per ton weight on drivers
2460	159.3	2302.9	44.7	42.59	5.56	1403	14.20
2455	202.0	2309.2	45.2	47.32	6.35	1601	16.20
2458	---	---	--	47.32	---	---	---
2441	532.7	1955.1	25.0	56,78	13.96	3518	35.60
2430	540.6	2207.7	30.5	57.03	14.16	3555	36.00
2432	516.7	2150.8	35.7	57.03	13.54	3398	34.40
2433	649.7	2351.3	35.4	57.03	17.02	4272	43.35
2439	534.1	2283.6	36.1	56.78	13.99	3527	35.65
2446	525.1	2350.6	36.1	56.78	13.76	3468	35.10
2447	434.4	2564.1	43.4	56.78	11.38	2869	29.05
2448	481.1	2427.6	46.2	56.78	12.60	3177	32.15
2454	--	----	--	66.78	---	---	---
2461	475.6	1733.9	21.9	66.25	10.68	2692	27.25
2440	499.0	2405.8	36.5	66.25	11.20	2825	28.60
2442	446.8	2359.4	37.2	66.25	10.03	2529	25.60
2443	494.5	---	43.5	66.25	11.10	2799	28.30
2444	648.0	2243.9	31.6	75.71	12.73	3210	32.50
2445	665.6	2510.0	38.3	75.71	13.08	3297	33.35
2452	896.1	2364.2	31.5	85.18	15.65	3945	40.00
2462	877.4	2273.3	34.1	85.18	15.32	3863	39.10

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TABLE NO. 14

EXPERIMENTAL DATA.

Pacific Type Locomotive No. 89. Pennsylvania Railroad.

Tested at Altoona, Pa.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar pull. pounds	pounds per ton weight on drivers
2801	180.0	756.1	31.0	28.24	15.49	2390	33.90
2818	143.3	937.7	27.8	28.24	12.33	1910	27.10
2802	176.9	1055.1	30.2	28.24	15.23	2349	33.30
2817	154.3	1328.8	42.8	28.24	13.28	2049	29.00
2814	224.1	1265.1	29.4	37.65	14.47	2232	31.60
2803	263.1	1356.4	32.0	37.65	16.98	2620	37.20
2804	269.8	1356.7	36.2	37.65	17.34	2687	38.20
2808	171.6	1424.0	49.8	37.65	11.08	1709	24.20
2826	357.8	1489.2	23.8	46.90	18.48	2861	40.60
2807	375.6	1529.3	30.8	47.06	19.40	2992	42.50
2815	324.9	1554.1	37.3	47.06	16.78	2589	36.80
2809	172.7	1731.4	50.7	47.06	8.92	1376	19.50
2810	177.0	1735.4	51.7	47.06	9.14	1410	20.00
2816	288.0	1741.5	25.0	56.47	12.39	1912	27.18
2813	366.0	1844.7	32.9	56.47	15.79	2436	34.50
2811	553.0	1875.6	35.7	56.47	23.80	3672	52.00
2825	450.8	1880.0	41.0	56.28	19.40	3004	42.60
2819	468.4	1967.2	25.6	65.66	17.28	2675	37.90
2821	515.2	1993.6	32.8	65.66	19.00	2843	41.75

TABLE NO. 14 (CONT'D)

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar pull. pounds	pounds per ton weight on drivers
2820	474.1	1994.3	41.2	65.66	17.49	2708	38.40
2812	376.8	2016.0	36.3	65.88	13.90	2144	30.40
2834	526.0	2043.7	26.8	75.04	16.98	2629	37.30
2827	588.3	2065.4	30.2	75.04	18.99	2940	41.40
2823	644.9	2116.8	33.8	75.04	20.82	3223	45.80
2838	516.8	2265.4	27.5	84.42	14.83	2296	32.60
2840	645.1	2350.1	37.5	84.42	18.51	2866	40.65
2839	625.2	2355.2	36.1	84.42	18.71	2777	39.40

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TABLE NO. 15

EXPERIMENTAL DATA.

Consolidation No. 1499. Pennsylvania Railroad.

Tested at St. Louis, Mo.

Test Number	Horse-Power Friction	Horse-Power Indicated	Cut-off in per cent of stroke	Miles per hour	Machine Friction Expressed as M. e. p. pounds	Drawbar Pull. pounds	pounds per ton weight on drivers
110	85.1	365.7	22.4	6.70	19.97	4764	47
111	81.0	454.5	30.4	6.72	18.97	4524	52.3
103	133.0	650.0	22.8	15.40	13.57	3237	37.4
109	106.4	587.6	20.88	13.55	12.35	2944	34.1
112	149.5	779.3	29.2	13.24	17.74	4233	48.4
118	141.3	930.5	39.3	13.40	16.57	3953	45.6
108	161.8	895.2	41.4	13.23	19.23	4584	52.9
116	187.0	975.1	31.3	19.95	14.74	3513	40.5
115	187.5	1036.1	33.96	20.04	14.70	3509	40.5
102	187.8	803.2	22.16	26.63	11.09	2644	30.6
105	257.9	951.4	28.03	26.20	15.48	3693	42,65
113	206.3	968.2	30.12	26.37	12.28	2932	33.80
106	276.1	1050.3	32.94	26.73	16.24	3873	44.75
117	248.0	1023.7	35.30	26.68	14.61	3485	40.4
101	203.4	851.7	42.14	26.66	11.99	2860	33.1
104	207.1	803.1	45.09	26.72	12.18	2806	32.4
114	170.4	682.2	,49.80	26.71	10.03	2392	27.6

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TABLE NO. 16

Presenting Specifications of the Locomotives from which Test Data was obtained.

Specifications of Locomotives.

No.	Road	Number of Engine	Type	Total Weight Pounds	Weight on drivers Pounds	Cylinder Dimen-sions.	Boiler Pressure pounds/ sq. in.	Driver Diameter inches	Type of Valve	Type of Gear
1	P.R.R.	1499	Consolidation	194200	173200	22"x28"	205	56"	Balanced Richardson	Stevenson
2	L.S.&M.S.	734	Consolidation	181300	162600	21"x30"	200	63"	"	"
3	M. C.	585	Consolidation	189000	164500	23"x35"x32"	210	63"	"	"
4	P.R.R.	387	Consolidation	249500	219900	25"x28"	205	62"	Piston	Walschaert
5	P.R.R.	1134	Consolidation	238300	211000	24"x28"	205	62"	"	"
6	I. C.	958	Consolidation	223000	200900	22"x30"	200	63"	"	Stevenson
7	Schenectady	1	American	85000	56000	17"x24"	140	63"	D-Slide	"
8	P.R.R.	5266	Atlantic	184167	110000	20-1/2"x26"	205	80"	Wilson double Ported Slide	Stephen-son
9	P.R.R.	318	Atlantic	185400	127900	22"x26"	205	80"	Piston	Walschaert
10	A.T.&S.F.	535	Atlantic	201500	99200	15"x25"x26"	220	79"	"	Stephenson
11	N.Y.C.H.R.	3000	Atlantic	200000	11000	15-1/2"x26" x 26"	220	79"	"	"
12	P.R.R.	877	Pacific	293200	179900	24"x26"	205	80"	"	Walschaerts
13	P. R. R.	3395	Pacific	317000	197800	27"x28"	200	80"	"	"
14	P. R. R.	89	Pacific	234200	141000	22"x26"	205	80"	"	"